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ORIGINAL ARTICLES

FUMIGATION AND OTHER METHODS OF DISINFESTATION OF PLANT MATERIALS AT INDIA'S PORTS

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(Received for publication on 17 March 1949)

(With Plates V and VI)

A NUMBER of very destructive foreign insect pests like the San Jose Scale, Fluted Scale, Woolly Aphis and Potato Tuber Moth and plant diseases such as Bunchy top disease of banana have found their way into India due to lack of proper inspection and disinfestation facilities at our ports and are now causing annually a loss amounting to several crores of rupees to the country and are a menace to the production of food and some other valuable commodities. Fortunately, there are still a very large number of insect pests and diseases in other parts of the world which have not so far entered India*; but with increased commerce and rapid means of communication they may do so any time unless we adopt immediately very efficient plant quarantine measures, as has been done by other agricultural countries, like the U. S. A., Holland, France, etc. The present methods adopted at Indian ports are over 30 years old when scientific agriculture was in its infancy in this country. The need for fully equipped Plant Quarantine Stations at ports—sea, air and on the land frontiers—is of absolute necessity; otherwise our country will very soon be flooded with insect pests and diseases which may ultimately ruin agriculture completely. The Government of India have appreciated the importance of this problem and have decided to establish a quarantine service as a part of the Directorate of Plant Protection, Quarantine and Storage of the Ministry of Agriculture.

Furthermore, we have certain international obligations to meet. Just as we are anxious to see that foreign insect pests and diseases do not enter our country, we should see that Indian insect pests and diseases do not leave this country in plant material and plant products which we export. Not only our reputation is already at stake but Indian commerce is also suffering greatly, because many of the plant products which we export on arrival at the destinations in other countries are found to be infested with various kinds of insects and diseases, often greatly reducing the quantity and deteriorating the quality of the commodity. There is, therefore, also need for disinfestation and certification of all the plant products that we export to meet the requirements of foreign countries as well as in the interest of our own trade. This can only be done with modern technique and a sufficiently large and fully trained plant quarantine staff at our ports.

This article has been prepared for practical use at ports so that the latest procedures are adopted to inspect and disinfest insects by fumigation and other methods, the various plant materials or plant products that are imported into India or are being exported to foreign countries.

A separate Compendium for methods to be adopted against plant diseases will be issued at a later date.

* Appendix III gives some of the more important pests found in various countries, but not recorded so far in India.

Existing facilities and disinfestation methods employed at ports

To prevent the entry of insect pests and plant diseases into India, the Destructive Insect and Pests Act was passed by the Government in 1914. Under this Act and the rules framed thereunder, living plants with the exception of fruits and vegetables meant for consumption, seeds and some other specified commodities, are fumigated with hydrocyanic acid gas at the port (sea) of entry. There is no restriction at present at air ports or land frontiers of India. Importation of foreign plant material is permitted only through seven ports which are Bombay, Calcutta, Cochin, Dhanushkodi, Madras, Negapatam and Tuticorin. The fumigation is at present done by the staff of the Collector of Customs. Thus, the staff carrying out the fumigation have no knowledge of insects which may be infesting the imported plant material nor are they in a position to see the effect of fumigation on them or even on plants under disinfestation. In fact they are not required to do any inspection before or after fumigation. The procedure laid down is in accordance with the directions published in Notification No. 13-C, dated 7 November 1917 of the Government of India, in the late Department of Revenue and Agriculture (*vide* Appendix I). Briefly, there is no inspection, as stated already, before fumigation in order to determine the nature of insect concerned, nor after fumigation to ascertain whether the pests present have been destroyed or not. Moreover, all plants and plant products receive a uniform routine treatment, irrespective of their own tolerance and susceptibility of the pests to hydrocyanic acid gas. In most cases the 'Pot' method of HCN generation is employed, viz. the gas is generated by the action of sulphuric acid on cyanide in a vessel. Wooden boxes (Plate V, fig. 1) with the internal capacity of 98·64 c.ft. or a brick chamber as at Calcutta are used as fumigatoria. For 100 c.ft. of space the chemicals used for the generation of HCN gas are: Potassium cyanide (98 per cent): $\frac{1}{2}$ oz; sulphuric acid and water: 1 fluid ounce each. The time required for the completion of the fumigation process is three quarters of an hour.

At Bombay the fumigation chamber* is 8 ft. $\times$ 6 ft. $\times$ $3\frac{1}{2}$ft. It is fitted with a fan for circulation of the gas. For the fumigation chamber which has a capacity of 168 c.ft. one ounce each of potassium cyanide (50 per cent solution) and sulphuric acid dissolved in equal volumes of water are used. The packages of imported plant material are unpacked so as to expose the surface of the articles to be fumigated. They are then placed in the fumigation chamber which is then securely closed. The chemicals (KCN and H_2SO_4 solution) are then poured into the respective bottles attached to the generating chamber. In the case of living plants, bulbs, etc. fumigation lasts for three-fourths of an hour, after which the gas is let out by opening a valve at the top and working the fan inside for two hours.

Organization of proper plant quarantine

The above account shows how deplorably primitive are the methods adopted at present. As the insect infestation is not examined either before or after treatment and as the dosage of the fumigant used is uniform without taking into consideration

* This has now been scrapped as unfit for use

the insect concerned and its habit as well as the particular live-plant, the disinfestation as carried out at present may not serve the purpose for which it is intended, the insect never being killed or as it has often happened, the plant succumbing on account of over dosage. There is, at present, no arrangement by which all packing material of plant origin and all the various imported plant products are examined and treated. Experience in other countries, e.g. the U.S.A. during past twenty-five years has shown how foreign insects can enter the country even through these materials. There is also, at present, no arrangement for vacuum fumigation of consignments like cotton and tobacco bales which are too tightly packed to permit penetration of the gas under atmospheric pressure. To organize the latest methods to inspect imported plant material and plant products and adequately disinfest them, the following are desideratum :

1. Plant inspection house fully equipped with fumigants, fumigation chambers, sterilisers, hot water tanks, vats for oil treatment, incinerators, etc.
2. Glass houses for growing plants under quarantine.
3. Properly qualified quarantine staff who can examine all imported material and take adequate measures for cleaning such plants and plant products that require to be disinfested.

The Directorate of Plant Protection, Quarantine and Storage of the Government of India (Ministry of Agriculture) is taking steps to provide the above first at the main ports of Bombay, Calcutta and Madras.

FUMIGANTS

Gaseous poisons used for killing insects are called fumigants. The process of using these gaseous poisons is called fumigation. A very large number of fumigants has been tried for plant quarantine work in various parts of the world. Three of the fumigants most commonly used are hydrocyanic acid, methyl bromide and ethylene oxide. Their application as well as of other gaseous poisons is not only safe but also gives best results when plants and plant products are fumigated in tight enclosures.

Hydrocyanic acid

This is one of the most toxic fumigants in use. It is a colourless gas with a boiling point of 25·7°C. (or 78·3°F.). The liquid HCN manufactured by the American Cyanamid Co. is reported to boil at 79·7°F. under normal atmospheric pressure. The freezing point under normal atmospheric pressure is 5°F. The specific gravity of the liquid is 0·6970. Specific gravity of the gas is 0·9348. Molecular weight is 27. On account of its being lighter than air, its diffusion is mainly upwards and outwards. Under normal atmospheric pressure it does not quickly penetrate closely packed materials like bales of cotton or sacks of grain, flour, etc. To overcome this, such materials have to be fumigated in a partial vacuum. *Very great care has to be taken in using this gas.* It should be used only by trained and experienced operators who must also put on gas masks specially meant for use with HCN. The masks used in the U.S.A. are known as type M-27 with renewal canisters of type C-7.

In England, the 'Degea' masks with initial G and a blue filter are used for HCN gas. A mask of the same manufacture with initial J and a blue filter with brown band is specially intended for use with Zyklon. The 'Puretha' mask with initial D and a white filter can also be used for HCN.

For plant quarantine work fumigation is carried out by (i) generating the gas by the Pot method, (ii) using liquid HCN available in steel containers, (iii) using HCN discoids or Celophite units which usually consist of the gas absorbed in fibrous discs of wood or paper pulp and (iv) using Zyklon a proprietary article which consists principally of liquid HCN absorbed in a porous earth known as 'kieselguhr'.

'Pot' method and fumigation. Hydrocyanic acid was first used for economic purposes in 1886 by Coquillet of the U. S. Department of Agriculture for controlling scale insects on citrus trees. This led to the extensive use of what is called the 'Pot method' in the fumigation of orange trees in California. This method is even now used in some ports for fumigating railway freight carriages having cotton seed or foreign raw cotton. Portable equipments for adopting the 'Pot method' for HCN generation are used in such fumigation work. The chemicals used are, sodium cyanide mostly in the form of 'eggs' and sulphuric acid weighing one ounce each. The proportion of these chemicals and water used for fumigating plant material other than living plants is as follows :

Sodium cyanide (NaCN)	1 lb.
Sulphuric acid (H_2SO_4)	$1\frac{1}{2}$ pints
Water	3 pints

For fumigating railway freight carriages having a capacity of 4,606 c. ft. 5 lb. of NaCN 'eggs', one gallon of H_2SO_4 and one gallon of water are used against the pink boll worm and the Cotton boll weevil. The portable HCN generator used in this connection consists of a metal cylinder in which a perforated metal basket slides up and down on a central shaft controlled by the pressure developed by the generated gas. All preliminary preparations are made by keeping the end of the HCN discharge tube from the generator properly inside the carriage, the doors completely closed and all openings and leaks sealed with masking tape and thick brown paper. Special warning posters are attached on both sides of the carriage to warn people not to enter or open the doors of the carriage while it is being fumigated. The required quantity of water is first put into the generator through the openings on one side at the top. The necessary quantity of sulphuric acid is then added gradually to the water. This process *should not be reversed* by adding water to the sulphuric acid as it would result in violent reaction. The opening is then carefully closed. The NaCN eggs are then placed in the metal basket which is held above the acid with the help of a set screw until the opening of the central shaft is securely closed and everything is ready for the gas to be generated. The basket having the NaCN eggs is then allowed gently to slide into the acid. HCN gas is evolved immediately and flows out of the discharge hose. In using this apparatus care must be taken to see that the basket holding the NaCN eggs is held out of the acid until the opening in the top of the generator is securely closed. The evolving of the

gas and the resulting pressure is indicated on a gauge. When all the gas has been evolved and passed out, the discharge tube is removed and the opening through which it was placed inside, is also sealed. The gas is allowed to act for eight to twelve hours. The doors of the carriage are then opened.

Liquid HCN in cylinders. The commercial development of pure HCN in the liquid form and the packing of the gas into small containers by absorbing it in an inert material has enabled great strides to be made in fumigation technique. The packing of liquid HCN in cylinders is done by a large number of firms both in England and America. The HCN cylinders are available in several sizes and forms (Plate V; fig. 5). These cylinders should always be kept in upright position and stored in a cool, well ventilated place, shaded from the sun. Particular care to ensure these conditions in India is very necessary. If no arrangement to obtain the above conditions is possible by using artificially cooled rooms, the cylinders may be kept submerged in water.

Operation of liquid HCN cylinders. The construction of HCN cylinders varies to a certain extent with the firms manufacturing them. The mode of their operation also varies with the construction and instructions for this as well as the way in which they are connected with the fumigation equipment, will be given by the manufacturers.

Volatilizer. This is an important part of the fumigation equipment used in connection with HCN cylinders which vaporizes the liquid HCN so that it enters the chamber as a gas (Plate V, figs. 5 and 6). It consists of a copper coiled tube immersed in a tank of water (Plate V, fig. 6). A short length of rubber hose connects the HCN cylinder with one end of the coil while the other end of the coil enters the vacuum chamber through a side connection. The tank of the volatilizer is made of steel with a removable top and is equipped with gauge glass, thermometer and a source of heat which is usually either steam or water heated by an electrical immersion unit. The vacuum in the chamber draws into it the liquid HCN from the cylinder through the volatilizer. The vacuum delivery connection (Plate V, figs. 4 and 5) connects the cylinder with the volatilizer. During operation the copper coil is heated so that as the liquid HCN flows through it, it immediately vaporizes before entering the vacuum chamber.

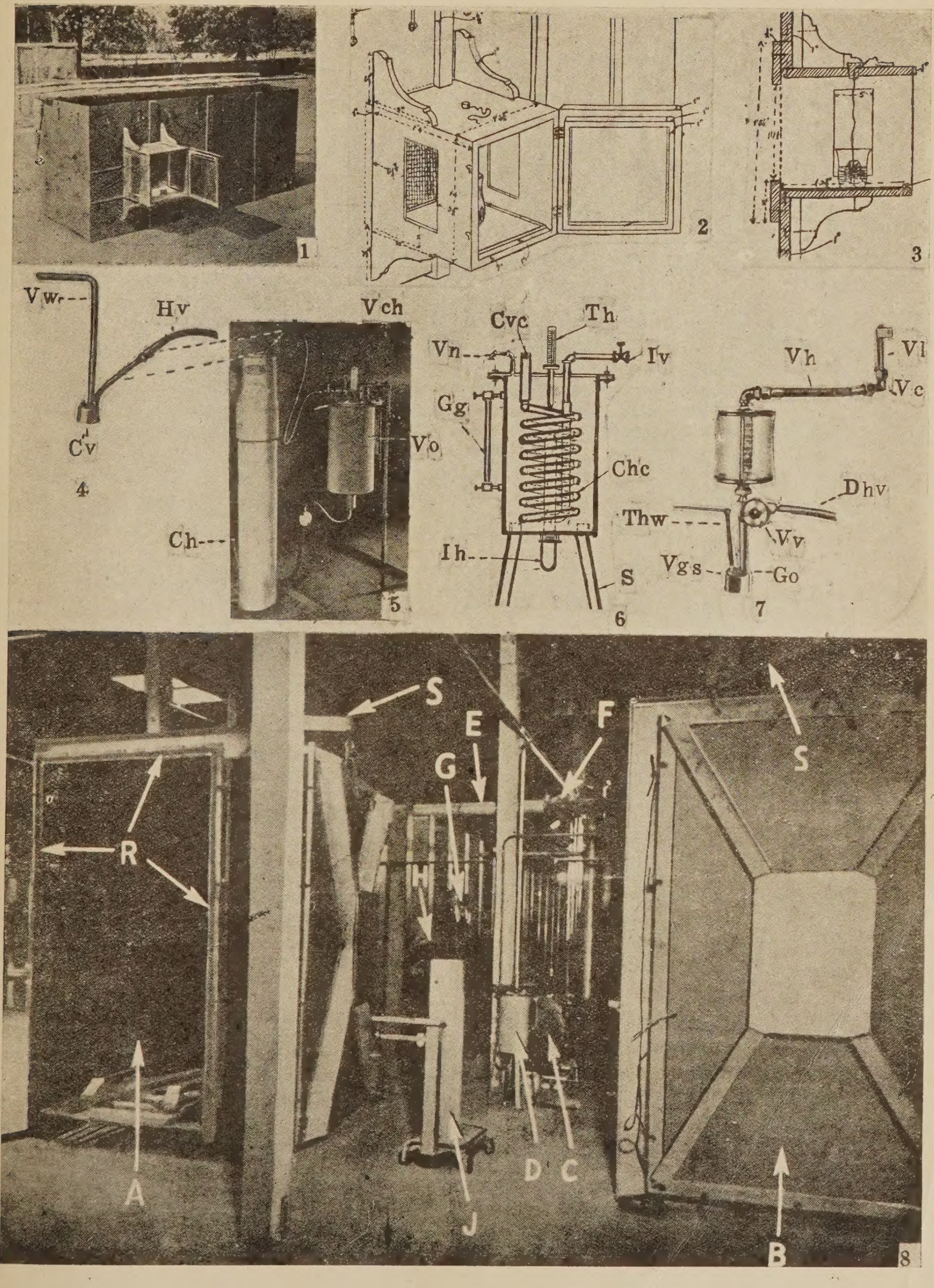
Application of liquid HCN. When very large quantities of materials are fumigated requiring the use of more than a pound of liquid HCN gas, the dosage to be used for fumigation is measured by placing the HCN cylinder on a platform scale. For example, if the dosage of liquid HCN to be discharged into the chamber is 4 lb. and the beam balances at 250 lb. to obtain the required dosage, the beam is moved back to 246 pounds on the scale. Then the valve gas spindle on HCN cylinder valve is opened slowly from half to two turns. Inlet valve on volatilizer is next slowly opened. This permits the liquid HCN to pass into the volatilizer from the cylinder. The introduction of the gas has to be regulated so that the flow is slow enough to prevent the pipe leading from the volatilizer to the vacuum chamber from cooling off appreciably. The scale beam is watched and when it begins to tip indicating that the required dosage has been discharged, the inlet valve on volatilizer

is closed. Then valve gas spindle on cylinder is closed. Inlet valve is opened for a moment to permit the liquid HCN in the hose line to be discharged into the volatilizer. Then, the inlet valve on volatilizer is closed. In the case of small vacuum chambers when the dosage and HCN used is less than a pound, a special 'Measuring Cup' or HCN applicator graduated in ounces having a capacity of ten ounces of liquid HCN is used. Its position and connections may be seen in Plate V, fig. 7. Its tubular lower end is connected to the gas outlet of the cylinder. At the top of the cup is a vent hose which is about 10 ft. with a female connection at each end. The further end of the vent hose has a vent connection which in turn is connected to a vent line. The vent line which consists of soft seamless copper tubing should be run from the operating point outdoors and up in the air for discharge of the gas-laden air which issues from the cup during filling. The discharge hose is 6 ft. in length and has a female connection at the end, which connects it with the valve of the cup and a male connection at the other end which connects it to inlet on volatilizer. A special T-handle is used for operating HCN cylinder valve with measuring cup in its place as shown in Plate V, fig. 7.

HCN discoids or celophite units. These discoids or celophite units consist of HCN absorbed in an inert porous and absorptive material like wood or paper pulp cut out in the form of thin discs. For the purpose of stabilization of the gas the absorbent is acidified. Some manufacturers included a warning gas also. The Aero brand of HCN discoids produced by the American Cyanamid Co., contain HCN of 96 per cent to 98 per cent purity and have a thickness of 0·10 inch. They are packed in 16 oz. cans with discoids of $\frac{3}{8}$in. diameter or in 40 oz. cans with discoids of $\frac{5}{8}$ in. in diameter. In England, discoids about $5\frac{3}{4}$ in. in diameter and 5/16 in. in thickness each containing one ounce of liquid HCN are available also in cans. The cans containing the discoids have to be opened with special openers. The advantages of the discoids are that (i) the gross weight of the cans is very little, (ii) only a can opener and a gas mask are required for their use, (iii) there is no need of weighing and mixing of chemicals and (iv) as they do not crumble or break they are clean, leave no dirt and can be easily disposed off after the fumigation is completed. The HCN in them is completely vapourized in about one hour after they are distributed.

In India, specially, during hot weather when large quantities of the discoids are to be used at one time, they should be pre-cooled by keeping them in a refrigerator overnight or keeping them immersed in a tub of water and adding ice to keep them cool until needed. The use of dry ice may also be resorted to. In this case about 20 lb. of dry ice would be necessary to be applied to each case containing 24—40 oz. cans, for one to three hours, the longer period being preferable. Individual discoids should never be handled. These discoids are well suited for atmospheric fumigation chambers but in plant quarantine work their best use is in ship fumigation.

Zyklon. This is a proprietary product consisting of (i) a prepared inert porous earth called kieselguhr in which has been absorbed liquid HCN, (ii) a lachrymator and (iii) various stabilisers which stabilise the chemically unstable liquid HCN. Zyklon looks like granulated cork and is packed in tin cans, each can containing a definite quantity of available HCN mentioned outside on the label. The cans are opened


1
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Dhv
Thw
Vv
Vgs
Go
7
S
E
F
G
H
R
S
A
J
D
C
B
8

EXPLANATION OF PLATE V

FIG. 1. Photograph of a wooden fumigation box used at present at some of the Indian port (After Fletcher)

FIGS. 2 and 3. Sketches showing the construction of HCN generating chamber of the wooden fumigation box (After Fletcher)

FIG. 4. Photograph of HCN cylinder valve (*Cv.*) showing the hose to volatilizer (*Hv.*) and the valve wrench (*Vw.*) (Courtesy American Cyanamid Co.)

FIG. 5. Photograph showing the HCN cylinder (*Cy.*) and a volatilizer (*Vo.*) placed near the vacuum chamber (*Vch.*) and the connection between the former two. (Courtesy American Cyanamid Co.)

FIG. 6. Diagram to show the construction of a volatilizer. *Cvc* : Connection to vacuum chamber ; *Th* : Thermometer ; *Vn* : Vent ; *Iv* : Inlet valve ; *Gg* : Gauge glass ; *Chc* : Copper heating coil ; *Ih* : Immersion heater ; *S* : Supports. (Courtesy American Cyanamid Co.)

FIG. 7. HCN measuring cup. (Courtesy American Cyanamid Co.) *Vl* : Vent line ; *Vc* : Vent connection ; *Vv* : Valve 'A' ; Vent hose ; *Dhv* : Discharge hose to volatilizer ; *Go* : Gas outlet ; *Vgs* : Valve gas spindle ; *Thv* : T handle wrench (Courtesy American Cyanamid Co.)

FIG. 8. Photograph of a dual vacuum fumigation chamber showing its various parts. (Courtesy Pottstown Metal Product Co.)

A : & B : Rectangular chambers

C : Vacuum pump

D : Volatilizer

E : Suction pipe connecting vacuum pump and chamber

F : Valve in suction line providing control to enable the one pump to evacuate either chamber as desired

G : Vacuum gauge

H : Vacuum breaker valve

J : HCN Cylinder

R : Rubber gasket

S : Roller bearing jib crane on which door is swung

with a special hammer and the contents distributed as desired, usually on sheets of paper so that the residue can be easily collected and thrown off in a dust bin. The addition of a lachrymator or a warning gas in Zyklon provides an additional measure of security for operators both during and after actual operations. It also obviates complicated manipulation of cumbersome apparatus. As Zyklon is packed in light but strong cans, the cost of transportation and handling, as in the case of the discoids is reduced considerably. Another advantage is that it is capable of easy distribution and maximum concentration is obtained owing to speedy exudation of the gas from the large surface area of material exposed.

Fumigation of railway freight carriages with HCN. When a large number of freight carriages have to be disinfected, their fumigation can be carried out in specially large chambers made of concrete. Liquid HCN is used for fumigation, the dosage being 4 lb. per car for eight to twelve hours. In these fumigation houses one to twenty-five carriages can be fumigated at one time. The sliding doors present on each end and between the compartments can be made airtight for atmospheric fumigation. When large quantities of HCN are used, these fumigation houses should have special arrangements with evacuation fans for removal of gas by thorough 'air washing' and tall chimneys so that evacuated gas is released out high up in the air.

HCN fumigation of ships at ports. In modern times shipping lines perform a great deal of fumigation of ships to eradicate cockroaches, bed bugs and rats. Besides these routine fumigations, it has of late been found necessary to fumigate specially cargo ships harbouring dangerous insect pests as a quarantine measure. HCN discoids have been found to be the most suitable for such fumigation work. The following procedure should be adopted when fumigating ships :

1. A day or several hours in advance of the fumigation, notices should be placed in different parts of the ship warning the crew that the ship is to be fumigated at a particular time. If the ship is provided with a loud speaker arrangement, an announcement regarding the fumigation is made over it. In the case of foreign ships this announcement should be in the languages of the crew. All the crew and passengers if any must be asked to leave the ship and they should be taken to a place of safety. The Plant Quarantine Inspector-in-charge of the fumigation should then in company of the ship's Officer-in-charge make an inspection of the entire ship. This is made to find out exactly the places harbouring the pests which need special attention and secondly to determine the presence of any unauthorized persons on board ; if any of these are found they should be removed from the ship.
2. The cubic capacity of the ship's compartments, hold, etc. is determined and the amount of HCN discoids to be used calculated.
3. The gangway and all other entrances of the ship are roped off, warning signs are placed at each entrance and a guard posted with strict orders to allow no one on board.

4. All timbers, pipe casings, dunnage, double walls, lockers and drawers and other insect harbouring spaces should be opened up to allow for free penetration of the gas. Bilge boards should be removed when possible, if not all, at least two on each side of the hold. All closets and doors specially those leading to the store rooms in the interior of the ship are opened up. All ventilators and portholes should be covered up and sealed to prevent leakage of the gas. All doors leading from the engine room to the holds and all watertight bulk heads should be closed. At least, two thick tarpaulins should be placed on each hatch battened down as for sea, leaving a small end of the tarpaulin unfastened at one corner of the hatch, for the purpose of scattering the HCN discoid in the hold.

5. The necessary number of containers of the discoids should, then, be placed at the point of their distribution alongside the open corner of each hatch.

6. The Plant Quarantine Inspector in-charge of the fumigation together with the ship's Officer-in-charge should again inspect all spaces to see all persons are out and that everything is ready. A signed statement to the effect that all the ship's personnel have been removed to a place of safety is then obtained from the ship's officer. *This is very necessary.*

7. When the fumigation operator is fully satisfied that everything is in readiness, he should put on a gas mask and proceed to release the discoids from the open corner of the hatch. In the case of fumigation for rats the dosage is ordinarily 2 oz. per 1,000 c. ft. with an exposure of two to three hours. In the case of insects normally it is 8 to 16 oz. per 1,000 c. ft. with an exposure of 12 to 14 hours. In some cases fumigation may have to be repeated so that any insects which survived the first fumigation are killed during the second. The HCN discoid cans should be opened one at a time and the operator standing on the deck must hold the can near the tarpaulin and scatter the contents in the hold. The tarpaulin should then be pulled tight and battened down. Life boats, dunnage on deck, lockers, etc. should also be examined for insects and these also fumigated, if necessary.

8. For fumigating the superstructure, cabins or state rooms at the top, the discoids must be scattered rapidly on to several layers of newspapers previously placed in the rooms to be fumigated, keeping the fibre cap on the container as much as possible between the operations when moving from one room to another. The operation of scattering the discoids from the can should be started at the farthest point from the exit, the operator always working towards the exit. The doors of the state rooms should be quickly closed as soon as the required quantity of discoids are dropped in them. *Gas masks should be worn by the operators during fumigation.*

9. After the ship has been under the gas for the required length of time, the fumigation operators wearing gas masks should remove the tarpaulins

and open up the hatches, ventilators, doors, etc. from the exterior. Ordinarily, the ship is quickly ventilated after fumigation, HCN gas being lighter than air. Difficulty is sometimes encountered in ventilating the holds, in which case a tarpaulin or canvas is hung over the hatch so as to deflect the wind into the hold. If necessary a portable electrically operated blower with a canvas chute can be used in freeing a hold from HCN gas. The superstructure of the ship should not be entered for at least 15 minutes after opening up, and the holds should not be entered for at least an hour.

10. A live rat in a wire cage is lowered to the bottom of each hold and left there for five minutes to test for gas. If the rat is unaffected, the operator-in-charge of the operation may go personally or see one of his men go through all spaces on the ship before it is declared free from the gas. Men making this test should wear gas masks, carry flash lights and be watched from the deck. The presence of HCN after ventilation can also be tested by using methyl orange test papers. These are small strips of orange coloured papers which in the presence of an atmosphere containing HCN, turn pink or red and are very sensitive to relatively low concentrations of the gas. 'If these test papers do not change within two minutes after exposure to a supposed concentration of HCN, the space is safe for human occupancy.

11. All pillows, mattresses, beddings, clothings, rugs, etc. should be taken on deck and thoroughly aired immediately after fumigation and before being used.

12. All port holes should be opened up for fresh air to enter the cabins.

Precautions to be taken in HCN fumigation. All fumigation houses of Plant Quarantine Stations where HCN fumigation is conducted should be provided with telephone for use in case of emergency. If HCN fumigation is being carried out elsewhere the location of the nearest telephone should be determined for use in case of accident. All operators must carry a bottle containing cubes of ammonium carbonate fortified with strong ammonia to be used as an inhalant in case of accidental inhalation of very small quantities of HCN. It must be remembered, however, that this is not an antidote. Even though very small quantities of HCN or one or two cans of HCN discoids are being used at a time, the operator must wear a gas mask. When opening up a fumigated space also the gas mask must be worn. Gas mask known as M-27 with renewal canisters of the Type C-7 used in the U. S. A. are recommended for use in India. The gas mask can only be used when there is enough oxygen to allow a safety lamp to burn. It should not be used in a concentration of HCN greater than indicated on the canister label. Every time a gas mask is used, after putting it on, it must be tested for tightness. This is done by pinching the hose and inhaling. The mask will collapse if perfectly tight. The life of the canister depends on both concentration of the gas and length of exposure to the gas. If the operator using a gas mask gets a tickling sensation in the throat

or if his eyes start smarting, it is an indication that the canister should be replaced by a fresh one. The operator using the old one should immediately go to fresh air. Canisters are comparatively cheap and should therefore be frequently replaced to avoid any accidents. Very great care must be taken of the gas masks ; they must be kept always in the original case in which they are received from the manufacturers. They must also be kept away from heat, moisture and atmosphere of HCN gas. As light deteriorates the rubber parts of the gas mask, it should not be kept in a glass front case. It is safer to examine a gas mask regularly to see that head harness has not lost its elasticity or that the outlet valve and face piece have no cracks. A stock of fresh canisters must always be ready at hand. All used and discarded ones must be destroyed. *Individuals with punctured ear drums should not undertake HCN fumigation even after using gas masks* although it is reported that such individuals have solved their difficulty by using ear plugs of cotton smeared with oil.

First aid kits used in the U. S. A. in connection with HCN fumigation consists of (i) pearls of amyl nitrite, (ii) ampoules of sodium nitrite, (iii) ampoules of sodium thiosulphate, (iv) one sterile syringe of 10 c.c. and (v) one sterile syringe of 50 c.c. In England, Coramine, Lobeline hydrochloride and caffeine are stocked for such purpose. These must be made available at all fumigatoria in India.

Another important apparatus that all fumigation houses should possess is an inhalator or Resuscitation apparatus. There are several types available administering a mixture of 93 per cent oxygen and 7 per cent carbon dioxide and others administering only oxygen. In England, the two types commonly used are (i) the Novox and (ii) the Novita.

A detailed account regarding artificial respiration and medical aid to be given in case of accidental HCN poisoning is given in Appendix II.

Methyl bromide

Methyl bromide is a comparatively new fumigant. Its insecticidal value was first accidentally discovered in France by Le Gaupil in 1932 when he used it mixed with ethylene oxide to eliminate the fire hazard of the latter. Its use in plant quarantine work in the U. S. A. was due to the efforts of Mackie and Carter. In 1935 it was used to fumigate potatoes against the Potato tuber moth. It is now used for fumigation of different kinds of live plants, fresh fruits, vegetables, potatoes, strawberry plants, citrus fruits, tomatoes, citrus nursery stock, deciduous fruit trees, pears, grains, dried fruits, dried pears, peas, seeds, etc. Fumigation with methyl bromide can be accomplished by means of a partial vacuum in special chambers, at atmospheric pressure, in chambers, in tight rooms, warehouses, railway carriages, under rubberized tarpaulins or in any tight container.

Properties of methyl bromide. Methyl bromide is a colourless, odourless highly volatile liquid, with a specific gravity of 1·732 at 0°C. and with a boiling point of 40·1°F. At ordinary temperatures it is a gas approximately 3·3 times as heavy as air. The properties which make it an ideal fumigant are :

1. High toxicity to a large variety of insects in egg, larval, pupal and adult stages.

2. Low chemical reactivity making it adoptable to a great variety of products including foodstuffs and tender plants because of low absorption, high penetrating power and lack of residual odour or taste.
3. Very low boiling point assuring complete gasification at all temperatures at which fumigation is practicable.
4. Low water solubility permitting the fumigation of products having a high moisture content. This is of great importance in the fumigation of live plants.
5. Low cost per unit of space fumigated because of small dosage required.
6. Ease of application.
7. Non-inflammable and non-explosive.
8. Highly penetrative.
9. Insects once exposed to its vapours under requisite conditions of time, temperature and concentration do not revive bringing about what is called ' delayed mortality '.

Containers of methyl bromide. Methyl bromide is available in 10, 50 and 150 pound cylinders or in one pound cans (Plate VI, figs. 2 and 6). Fig. 1, Plate VI shows the appearance of a cylinder. In order to facilitate rapid and complete removal of the liquid, a valve is fitted on the cylinder with a pipe reaching to the bottom of the container. Natural vapour pressure on the cylinders at 50°F. is—4 lb. per sq. inch ; at 60°F.—8·5 lb. ; at 70°F.—13 lb. ; at 80°F.—19 lb. ; at 90°F.—25 lb. ; at 100°F.—32 lb. These cylinders are so designed as to take advantage of the natural vapour pressure of the liquid. Sixty pounds of additional air pressure is also added to the cylinder before it leaves the factory. The natural vapour pressure and the additional air pressure will cause the liquid to rise through the central tube. In some type of cylinders manufactured in England there are two valves, one of which delivers vapour and the other painted red, delivers liquid. No air pressure is applied to the one pound can. Cylinders are provided with fusible safety plugs which will melt at 165°F. Cans will distort at 150°F. and burst at 185° to 190°F. So both the cans and cylinders should never be subjected to these very high temperatures. Glass sealed ampoules containing 20 c.c. of methyl bromide are also sold.

Applicators for use with cans. At any temperature above 40°F. liquid methyl bromide in 1 lb. cans is under pressure. The opening can be done with a special inexpensive device called the Jiffy can puncturer or opener (Plate VI, fig. 4). When the can is inserted into the steel band of the opener and the lever pulled, the can is punctured and the hole automatically gasketed so that the liquid flows through tubing into the fumigation chamber, box car, or other space. As the application is from outside the structure, this method provides maximum safety and even eliminates the necessity of a gas mask during the application. To enable the pressure within the can cause the liquid to flow through the tubing, the point of puncture should be the lowest point on the can but care has to be taken to see that the puncture is not made on the side seams. Special Jiffy applicators for use with cans are also

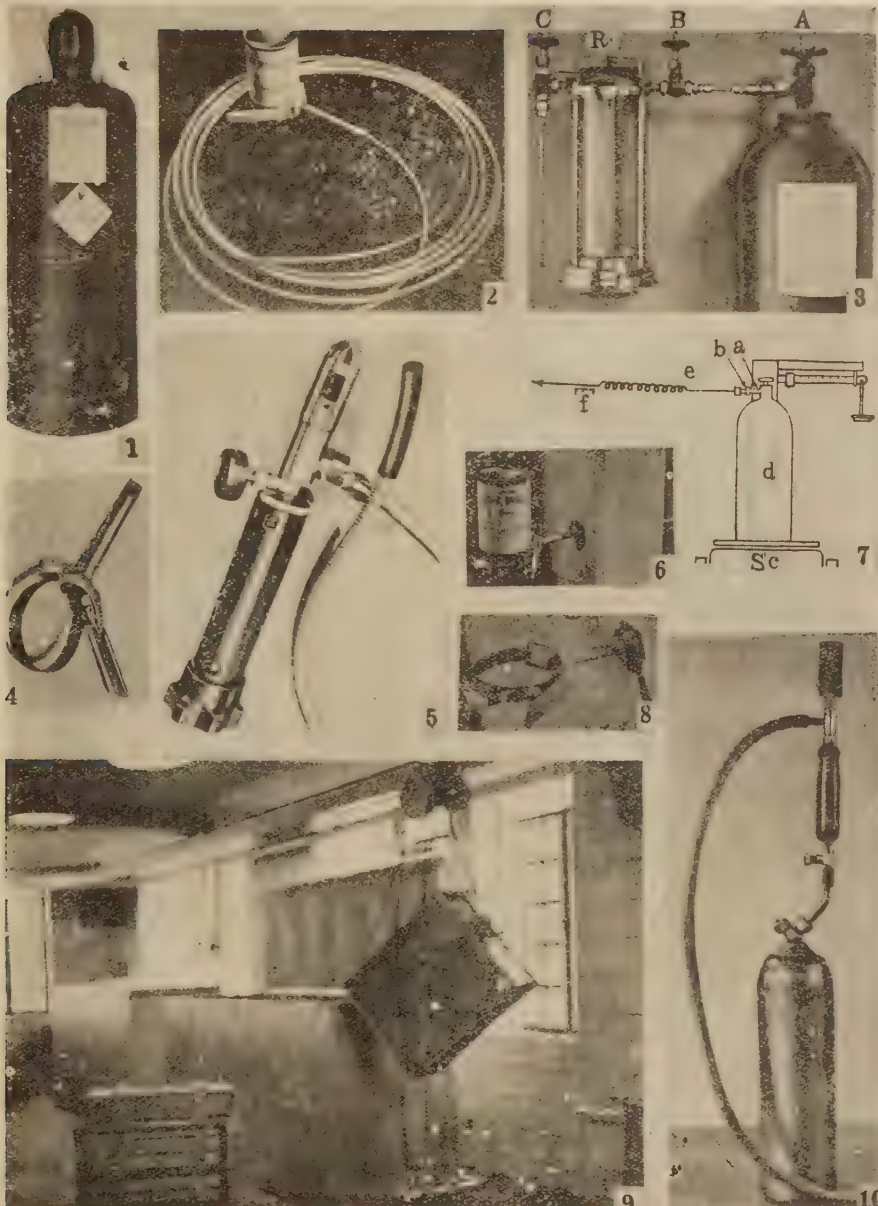
available for fumigating railway carriages and material under tarpaulins. Plate VI, fig. 2), Jiffy Fumigation Chamber Applicators (Plate VI, figs. 6 and 8) are also available. This applicator has to be screwed to the wall of the chamber by means of flange and is provided with a base to support the can. A tube extends into the chamber releasing the gas at a point above the load. For fumigation chambers in which less than one pound of methyl bromide is used for dosage, 280 c.c. applicators fitted for one pound cans have also been devised. Ordinarily, however, Plant Quarantine Stations in the U. S. A. prefer to use methyl bromide in cylinders.

Application of methyl bromide by direct weighing of cylinders. When large quantities of commodities are being fumigated and the quantity of methyl bromide used each time is several pounds, it may be measured by direct weighing of the cylinder as shown in Plate VI, fig. 7. The connections are made as follows: The cylinder (d) is placed on the weighing machine (Sc): a copper or Saran tube (e) is attached to the cylinder valve (a) by means of a reducer connection (b). If copper tubing is used it should be supported at (f) and coiled through several turns to eliminate any pulling strain on the cylinder. The cylinder is weighed carefully. The required dose having been computed, the scale is reset to the weight of the cylinder after the dose has been withdrawn. The cylinder valve is then opened and methyl bromide is allowed to flow through the tube into the fumigation chamber. When the beam tips, the valve is closed.

Applicators for use with cylinders. A number of applicators have been devised ranging in size form 100 c.c. to five pounds for use with methyl bromide cylinders. Plate VI, fig. 3 shows a 5 lb. applicator with glass calibrated in $\frac{1}{4}$ lb. steps. But similar ones are available with calibrations in steps of 1 c.c. or 2 c.c. The applicators have clamps which allow permanent fitting up on the outside of the fumigation chamber wall and a tube to connect the applicator to the chamber. The applicator is connected to the cylinder by means of a short length of copper tubing and a reducer connection. Cylinders are connected to the applicator by a single nut on the end of the reducer connection. While operating the applicator, all valves should first be tested to see that they are closed. Then the cylinder is connected to the applicator. When the cylinder connection is tight, the valve 'A' on the top of the cylinder is opened (Plate VI, fig. 5). Next the intake valve 'B' on the applicator is opened allowing the methyl bromide to enter the measuring glass through the stand-pipe opening at the bottom. If as it sometimes happens the flow of the liquid stops, the relief valve 'Rv' should be 'cracked' (opened for a few seconds and closed immediately) to relieve air pressure. When the proper level in the measuring glass is reached, the intake and cylinder valve should be closed. The outlet valve 'C' is opened permitting the methyl bromide to enter the fumigation chamber. As soon as the methyl bromide disappears from the measuring jar, the outlet valve 'C' is closed.

Calculation of dosage of methyl bromide. When a dosage of methyl bromide is calculated by weight the following formula is used:

Divide the volume of the vault in cubic feet by 1,000, then this quotient is multiplied by the dosage rate as expressed in pounds per 1,000 cubic feet.


1
2
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EXPLANATION OF PLATE VI

FIG. 1. A Photograph of a methyl bromide cylinder. (Courtesy Dow Chemical Co.)

FIG. 2. Jiffy methyl bromide can puncturer with Saran tube. (Courtesy Dow Chemical Co.)

FIG. 3. A methyl bromide 5-pound applicator for use with cylinders of methyl bromide. (Courtesy Dow Chemical Co.) A : valve on the top of cylinder ; B : Intake valve ; C : Outlet valve

FIG. 4. Jiffy methyl bromide can puncturer. (Courtesy Dow Chemical Co.)

FIG. 5. Photograph of Frigidaire halide leak detector. (Courtesy Dow Chemical Co.)

FIG. 6. Jiffy fumigation chamber applicator for use with methyl bromide can. (Courtesy Dow Chemical Co.)

FIG. 7. Diagram to show the method of application of methyl bromide by direct weighing of cylinder. *a* : Cylinder valve ; *b* : Reducer connection ; *d* : Cylinder ; *e* : copper tubing ; *f* : Support ; *Sc* : Weighing scale.

FIG. 8. Jiffy fumigation chamber applicator for use with methyl bromide cans. (Courtesy Dow Chemical Co.)

FIG 9. Photograph of a Prestolite halide leak detector. (Courtesy Dow Chemical Co.)

FIG. 10. Photograph of a tank for giving hot water treatment for imported bulbs (Photograph by V. P. Rao.)

For example, for a dosage of 1·5 pounds per 1,000 cubic feet in a 1,400 c. ft. chamber it would take $1{,}400/1{,}000 \times 1{\cdot}5 = 2{\cdot}5$ lb.

When a dosage of methyl bromide has to be measured the following formula is used :

Multiply the index of the desired rate (given below) by the capacity of the vault in cubic feet.

For example, for a dosage of 2 lb. per 1,000 cubic feet in a 31 cubic feet vault, $0{\cdot}52 \times 31 = 16{\cdot}12$ c.c.

The basic index is 0·26 c.c. per cubic foot per pound per 1,000 cubic feet.

Rate per 1,000 cubic feet	Index	
1 lb.	0·26	c.c. per c.ft.
1·5 lb.	0·39	
2 lb.	0·52	
2·5 lb.	0·65	
3 lb.	0·78	
3·5 lb.	0·91	
4·0 lb.	1·04	

Work carried out in the United States has shown that for practical purposes ½ lb. of methyl bromide per 1,000 c.ft. equals ½ hour of exposure or 10°F. difference in temperature, once a lethal dosage at any temperature is determined. If 100 per cent kill of an insect is obtained with a schedule of two lb. per 1,000 c.ft. for two hours at 80°F., a drop in temperature of 10°F., can be compensated by increasing the dosage of one half pound or by increasing the time, ½ hour. This has been found to be true in California also and can, therefore, be adopted in India too.

Fumigation of railway freight carriages with methyl bromide. Methyl bromide has always to be applied from outside the railway freight carriage by means of a copper or Saran plastic tube attached to a Jiffy can operator or methyl bromide cylinder whichever is being used. Duplicate can applicators should be available in case of breakage. The tube has to be introduced into the carriage through a hole drilled in the floor near the centre of the carriage or through any other convenient opening. The discharge end of the tube should be attached at the centre of the carriage near the ceiling by propping up the end of the tube. The opening of the tube has to be plugged and a hole drilled laterally allowing the mist of the methyl bromide towards the opposite ends of the carriage. As the Saran plastic tubing becomes a little brittle when cooled to about 32°F. it should be examined now and then to prevent gas leakage from it.

For obtaining best results in fumigating railway freight carriages, very great care has to be taken to thoroughly check for all possible leakage points and all these should be sealed with masking tape, caulking compound, bug putty, or strips of greased paper. An excellent caulking compound can be prepared by mixing 8 parts of asbestos, 3 parts of calcium chloride and 4 parts water by weight. As in Canada, brown paper liberally smeared with a good quality casein paste can be used. A paste made by adding lubricating oil to flour and mixing it to a putty-like consistency may also be used. In the U. S. A. special masking tapes manufactured by Minnesota Mining and Manufacturing Co., St. Paul (Minnesota) or the Industrial Tape Corporation, Chicago, (Illinois) are used. Heavily oiled kraft gummed tape can be used for surfaces on which it sticks well. Special attention has to be paid to the openings near the doors, and around the rollers of the door tracks.

Although it is safer for the operator to use a gas mask, it is not very necessary since methyl bromide is applied from the outside of the carriage. It has been found that one pound cans of methyl bromide are very convenient for fumigation of freight carriages. At first the cubic capacity of the freight carriage has to be ascertained and the dosage calculated according to the commodity to be treated. The application of the fumigant is made as follows :

The tins are clamped one at a time, in the Jiffy puncturing device fastened to the end of the tube. The puncturing has to be done as close to the bottom of the can as possible avoiding the soldered seam. As soon as the can is punctured the methyl bromide will leave the can under its own vapour pressure. A can will be emptied in less than 60 seconds and the methyl bromide will be discharged in the railway freight carriage as a fine mist changing immediately into vapour.

The actual application of the gas can be done by the operator standing on the ground by the side of the carriage or from the top of the carriage. In the latter case the can applicators are mounted on a small wooden platform to keep steady the cans against the back pressure of the gas.

When a methyl bromide cylinder is used, the copper or Saran plastic tube should be attached to the cylinder valve. The dosage should be measured by a weighing on a portable platform scale. No attempt should be made to release the methyl bromide in open carriage and then commence closing the doors and sealing. 10 to 15 lb. of methyl bromide with an exposure period of 10 to 18 hours would be required to fumigate a railway carriage (steel carriages of good construction may need only six to eight hours). As a safety measure to prevent persons from entering a carriage under fumigation, prominent warning signs should be pasted on both the doors before methyl bromide is applied.

At the completion of the fumigation period, both carriage doors should be opened from the outside to permit aeration. No one should be allowed to enter the carriage for at least half an hour. It is safer to find out whether aeration is complete or not by using a halide leak detector.

Fumigation of railway carriages should be carried out as far as possible in isolated yards far away from human habitation. If a large number of carriages have to be

fumigated it would be advantageous to segregate the carriages undergoing aeration on another track so that fumigation operators are not exposed to the gas emerging out of the carriages undergoing aeration. No hard and fast rule as regards the period of aeration can be made as it depends on the climatic conditions and air currents, but ordinarily six hours of continuous aeration may be necessary before the carriages are released for despatch for destination.

Fumigation of fruit in freight or refrigerator carriages with methyl bromide. It may often be necessary to fumigate fruit in railway freight carriages on the Indo-Pakistan border.

The procedure mentioned in the previous chapter may be used with success but the following additional precautions would have to be taken.

1. Under no circumstances should fumigation be attempted on chilled fruit or when ice is present in the bunkers.

2. Fumigation should not be attempted at temperatures below 65°F. or in excess of 95°F.

3. Bunker drains should be properly sealed and plugged to prevent leakage. The carriages must remain stationery during fumigation. All plugging and sealing should be removed at the end of fumigation.

4. The schedule for use in treating fresh packed pears in refrigerated carriage in the U. S. A. for the control of codling moth eggs and larvae has been found to be the application of 4 lb. of methyl bromide for an exposure of two hours.

5. Injection should be effected by means of a $\frac{1}{4}$ in. copper tube leading to the upper centre of the carriage well above the packed fruit or in the bunkers with the load divided one half to each end of carriage. Care should be exercised in placing the tube outlets so that the methyl bromide does not directly spray on the fruit. The end of the tube should be wrapped with a roll of rags or gunny and placed in an empty box held in the upper centre of the bracing of the carriage.

6. Both during injection and for a period of at least 10 minutes following, fans of not less than 10 in. diameter should be operated one at each end of the carriage. Following the completion of the two hour exposure, doors as well as all bunkers should be opened completely and allowed to aerate for a period of at least one hour before the carriage is iced.

7. Exposure should be for *two hours* only.

Fumigation of fruit under tarpaulins. Rubberized sheets have been found suitable for fumigating stacks of fruit boxes. The best tarpaulin for such a purpose is a light duck fabric coated heavily on one side with a plastic material impervious to methyl bromide gas. The reverse side is covered more lightly. Types of fabric treated with oil should never be used, as methyl bromide is an oil solvent. This type of fumigation under tarpaulin should be accomplished in the shade or at night. Boxes should be stacked not more than six feet high and arranged in a rectangular stack. Under no circumstances should chilled fruit be placed under fumigation. Fruit should

not be stacked and fumigated where direct sunlight strikes the tarpaulins. Fumigation should not be carried out at temperatures below 65°F. or in excess of 95°F. The stacking of the fruit boxes should be done in such a way as to provide two open aisles of about one foot width in the form of a Greek cross, extending through the entire length of the stack in opposite directions. This arrangement will facilitate gas diffusion. The stacks should be made on a gas tight floor, concrete or earth being preferred. Two electric fans of not less than 10 in. in diameter should be in operation on the floor at the two extremeties of one of the aisles one pointing towards the other in an upward direction. Fan operation should continue during injection and for a period of ten minutes following. Injection of methyl bromide can be made either from a large high pressure cylinder equipped with a proper measuring device or from one pound cans dispensed from approved applicators. In either case injection is made with the help of a $\frac{1}{4}$ in. copper or plastic tubing. The end of the tube should be wrapped tightly in gunny or rags and placed in an empty box at the upper centre of the stock. A number of empty boxes placed at the corners and edges of the stack and some at random on the top will hold tarpaulin above the fruit and create on air dome permitting better diffusion of the fumigant. Tarpaulin edges will have to be properly weighed down with 'sand snakes' or saw dust sacks to prevent leakage. Exposure to methyl bromide should be only for two hours.

Fumigation of plant material with methyl bromide. Ordinarily, temperature conditions in India will be suitable for fumigation of plants except in some parts where there are extremes of temperatures. In cold weather it would be necessary to warm the plants and any earth balls which may accompany them. This has to be done to avoid the need of using very high dosage schedules that would be necessary to kill insects completely at low temperatures. Two hours are usually sufficient to secure complete kill of insects.

Higher temperatures within certain limits increase the kill of insects and plant tolerances are not affected greatly until temperatures approach 90°F. At lower temperatures the resistance to the fumigant of both the insect and the plant increases. Plant tolerance for fumigation and higher temperatures are greatly increased during dormancy. So the best results in fumigation have been obtained in the case of dormant plants. Insect resistance for fumigation varies both with the stage of the insect and its location in or on the plant. For example some borers and miners are difficult to be killed.

Plants to be fumigated with methyl bromide must be moist. High humidity both during the conditioning for treatment and during the treatment tend to minimize plant injury. A wet gunny or a basin of water is therefore placed in the chamber in some plant quarantine stations.

Fumigation is best done at temperatures between 80° and 85°F. Balled plants should never be fumigated until the cut surfaces of the roots have had a chance to form a callus. This might require about ten to fourteen days. Conifers should be treated only during the dormant season. Fumigated plants drop their leaves but this is followed by a prolific flush of new growth. The method of loading a chamber is very important in fumigation of plants. Double decking of plants in

cans or balled plants should not be done as efficiency of the fumigant is reduced. In fumigating tender plants such as ferns, succulents, orchids and some palms, the velocity of the air current should never be so strong as to cause whipping and thereby injuring the plants.

Fumigated plants should be given proper airing and be protected against direct sunlight and dry winds. They should also be properly watered.

Fumigation of grain using methyl bromide. Procedures in warehouse fumigation using methyl bromide have advanced considerably in the U. S. A. Methyl bromide cylinders are used generally in such cases and the gas is released in the rooms by operators wearing gas masks and working inside the fumigation space. In England this method of fumigation is forbidden. Similarly in the early stages of the introduction of the gas for fumigation in India, it may be safer to undertake it with the operation being carried from outside the space to be fumigated. As India imports large quantities of food grains from abroad and there are great chances of importation of grain pests not so far found in this country, some method of fumigation of the imported grain is very necessary. The tarpaulin method of fumigation may be preferred if regular large fumigation chambers are not available. Tarpaulin fumigation should however never be attempted in a closely confined space. An open space should be preferred so that the gas can escape quickly following fumigation. The preliminary procedures are similar to those described for tarpaulin method of fumigation of fruit. The bagged grain which is usually stacked irregularly will have to be re-arranged properly, in a square area up to a height of about 5 or 6 ft. The flooring may preferably be of earth, concrete or other airtight surface free from cracks. A few bags should be stacked upright on the top of the whole pile to form a sort of dome. The exit end of the copper or plastic tubing leading from the methyl bromide cylinder or the can should be placed near the centre of the dome in such a way that the gas does not come directly into contact with the tarpaulin. The latter should be placed over the stack taking special care to leave two or three feet margin trailing on the floor. The sealing is done by laying sand bags or 'snakes'. The application of the required quantity of the gas may be done by placing the cylinder on a platform scale as already explained on page 324. Ordinarily 1 to 1½ lb. of methyl bromide per 1000 c.ft. of estimated space under tarpaulin are recommended for agricultural seeds and bagged grain. The exposure period should be 12 hours at a temperature above 60°F. In the case of finely divided products like flour, the exposure period should be extended to 18 hours. At the end of the fumigation period the tarpaulin should be partially pulled back from the fumigated material and the latter allowed to air for about an hour. The tarpaulin can then be entirely removed. Another half an hour should elapse for the fumigated material to be removed.

In the case of stored grain pests in rice bags atmospheric fumigation using 1 lb. of methyl bromide for 1000 c.ft. for 12-24 hours or vacuum fumigation using 3—4 lb. of methyl bromide for 1000 c.ft. for 3 hours, the gas being injected in a 27 in.—28 in. mercurial vacuum, is recommended. In the case of stored grain pests like *Tribolium confusum* (Confused flour beetle), *Tenebroides mauritanicus* (Cadelle), *Acanthoscelidus obtectus* (Bean weevil), *Ephestia kühniella* (Mediterranean flour moth), *Sitotroga*

cerealella (Angoumois grain moth), *Plodia interpunctella* (Indian meal moth), etc. attacking milled cereals of various kinds, wheat, maize and other grains, atmospheric fumigation using 1 –1·5 lb. of methyl bromide for 1000 c. ft. for 12—24 hours and vacuum fumigation using 1 to 2 lb. for 2—4 hours, the gas being injected in a mercurial vacuum of 27 in. —28 in. is recommended.

As regards maize and wheat for germination, the moisture should not exceed about 12 per cent and the fumigation period should not exceed the maximum limit. Bagged grain, etc. should not exceed depth of 30 ft.

Ship and barge fumigation with methyl bromide. The use of methyl bromide in ship and barge fumigation is fairly recent. In the case of ship fumigation the preliminary procedures are the same as those described under ship fumigation with HCN gas. Section of the ship which has to be fumigated, should be sealed off very carefully. The rate of methyl bromide to be applied is two pounds per 1000 c.ft. The temperatures should be above 60°F. for this dosage and the exposure period should be 24 hours. In the U. S. A. for fumigating parts of ships methyl bromide cans have been used with success, the application of the gas being done making use of the Jiffy chamber applicators as shown in Plate VI, figs. 6 and 8 but the methyl bromide cylinders will be equally good. In the case of holds of ships, care must be taken that the cargo is stacked carefully with space or an aisle between rows of stacks of boxes or sacks, etc. so that the gas diffuses and circulates properly and enables it to penetrate the sacks. Electric fans should be placed some on the top of the cargo and some on the floor so that the gas circulates properly and to prevent its stratification; these fans must be operated for about half an hour following application. The aeration period at the end of fumigation should be at least 12 hours. It is safer if tests with halide detectors are made for small concentrations of the gas before finally entering a fumigated space.

Fumigation of barges with methyl bromide has been found to be easier and very effective and is therefore used considerably in England and Canada. In the case of wooden barges considerable sealing of all leaks would be necessary to prevent leakage of gas but in the case of steel barges a thick rubberized tarpaulin on the top of the hatches battened as for sea, is sufficient. The dosage is 2 pounds per 1000 c.ft. at a temperature above 60°F. the exposure period being 24 hours. In the case of barges. aeration is quicker. As in the case of the holds of ships, the cargo must be stacked properly with space between rows of stacks. some space on the sides and on the top between the stack and the tarpaulin. Methyl bromide cans or cylinders can be used. When the latter is used, the entire fumigation equipment can be placed on the top deck or on another barge. If the barge to be fumigated is by the side of the pier, the fumigation equipment can also be placed on the pier. A long plastic (Saran) tubing has to be used to eject the gas to the top of the barge when released from the cylinder.

The method described above can also be used with success in the case of schooners as well as freighters. In the case of freighters having more than one hold, to obtain good results and conduct the fumigation successfully, it is necessary to see that the

gas circulates to all parts. To make this possible the copper tubing leading from the methyl bromide cylinders to each of the hold must by means of T connection be divided into two lines leading in opposite directions and each of these again has three final outlets. Use of pallet boards on which the cargo is placed, has been found to be very helpful in facilitating the circulation and penetration of the fumigant throughout the cargo. If freighters to be fumigated have elevators, their platforms should be left at the bottom of lower holds. Two fans should be used for each hold to circulate the gas and they will have to be operated for 30 minutes. The dosage and the period of exposure is calculated in the same way as in the case of barges. Great care has to be taken for the process of aeration of freighters at the end of treatment period of 24 hours. The operators wearing gas masks must at first remove only a couple of boards at each side of the hatch covers. Then at intervals of 30 minutes, more boards should be removed and by about eight hours all the hatches be completely uncovered. Halide detectors may now be used to see if there are traces of the gas and if found free from gas the operators still wearing gas masks can now enter the 'tween-decks and open all side doors of the hull from the inside. Then the port holes in cabins and crew quarters should be opened. The aeration of freighters of the ocean going types would be very difficult. In some cases atmosphere safe for human occupation has been found to reach only 68 hours after aeration began. This period may considerably be reduced if some arrangements are made by providing suitable ducts for drawing out high gas concentrations from the interior parts of the holds. Much work on this subject has still to be carried out.

Detection of the gas. In methyl bromide fumigation, greatest care has to be taken to see that there are no leaks in the chamber or in the applicator. Leaks can be detected by a halide leak detector. Cylinders of methanol (wood alcohol) or acetylene are used for fuel in these detectors and the flame passes through a copper disc. The presence of methyl bromide is indicated by the progressive change in colour of the flame from violet through green to a vivid blue depending upon the amount of bromide present (as indicated in the list given below) when the sampling tube of the halide detector is placed in air containing methyl bromide. These halide detectors are commonly used in checking gas leaks in refrigeration equipment.

Methyl bromide present—parts methyl bromide per million	Pounds of methyl bromide per 1000 c. ft.	Flame colour
0	0	Almost invisible
40	·010	Rather faint green
60	..	Moderate green
100	·024	Moderate green
130	·031	Strong green; slightly blue at edges
180	·043	Strong green; rather blue
240	·058	Strong blue-green
360	·086	Strong blue-green
800	·192	Strong blue

Two types of halide leak detectors are available in the U. S. A. One is called the Prestolite halide leak detector (Plate VI, fig. 10) and the other is Frigidaire halide leak detector (Plate VI, fig. 5). Prior to using the detector, care has to be taken to clean its throat. Only when the flame is strong and it comes out direct through the centre of the cone of the torch, that the latter will become red hot and if the flame spreads around the cone, it will not heat properly and often a green colour appears even in the absence of any halide. Should this happen, the torch has to be put out, cooled, cleaned and then relit.

The 'Just—Rite' halide detector burning petroleum ether, the Tilley lamp burning paraffin and the Bladon burning alcohol are used in Britain for detection of methyl bromide. Amongst these, the Tilley lamp is considered to be more sensitive and gives a slightly coloured flame with air containing 8 p.p.m. and a distinct colouration at 16 p.p.m. of methyl bromide. Whichever of the above mentioned five lamps are used, the operator must make himself thoroughly familiar with its performance in known concentrations before relying on its readings to enter an area after fumigation.

Protection of operators, using methyl bromide. Methyl bromide has to be handled carefully. Although dispensing equipments have been developed eliminating exposure and assuring maximum safety to the operator greatest caution should be observed when using it. Continued exposure even to low concentrations of the gas has to be avoided. Operators should use approved gas masks when exposed to the gas during fumigation. The mask prescribed for it is one equipped with a black canister type B for organic vapours, approved by the United States Bureau of Mines. Manufacturers' instructions given on the canisters must be closely followed by the operators. The masks should neither be used in known concentrations of the gas stronger than the limit mentioned on the canister nor for total exposure period longer than the recommended, as the life of the canister depends on the time in use and upon the concentration of the gas. The limitations of the mask and the canister must be known to the operator. Gas masks and canisters approved by the U. S. Bureau of Mines are made by the following firms in the U. S. A.

Manufacturer's name	Type	Canister
Mine Safety Appliance Co.	AB	GMA
E. D. Bullard Company	CM	CM—1
Davis Emergency Equipment Co.	M—L	C—L

'Purethka' masks supplied by Siebe Gorman & Co. are used in England.

Symptoms of methyl bromide exposure. Operators exposed to methyl bromide show very little or no symptoms of exposure at first. These come on gradually after several hours after inhalation of the gas. The symptoms are: (i) dizziness, (ii) blurred vision, (iii) sensation of fatigue, (iv) staggering gait, (v) slurring of speech,

(vi) nausea and vomiting, (vii) loss of appetite and (viii) abdominal pain. Overwhelming exposure results in difficult breathing. In case of exposure to the gas, the patient should be immediately taken into fresh air and given artificial respiration. A physician should be immediately sent for. The patient should be kept in a sitting or reclining position. Care must be taken to see that he does not fall or strike against anything. He must be kept comfortably warm, if necessary covered with blankets.

In experiments made on animals, it has been found that continued exposure to low concentrations of the gas causes paralysis ; but they have been found to recover when removed away from the environment of the gas. Exposures to higher concentrations have resulted in lung irritation which can become acute and severe after developing into typical confluent broncho-pneumonia. However, when exposures are irregular and at intervals of several days, the effects can be thrown off by the animals. In man slight exposure to the gas has been found to cause weakness, vertigo and dyspnoea. In more severe exposures there may also appear psychic disturbances, attacks of mania and transitory brachial paralysis. Double vision, amblyopia and aphasia have also been noted in certain non-fatal cases. In France, severe fatal poisonings as the result of inhalation of the gas while filling fire extinguishers have been reported. In the U. S. A. the two fatalaties and several less severe cases resulting from exposures during fumigation have been reported. Liquid methyl bromide when spilled on the skin causes burning.

Only experienced and trained staff should be permitted to handle liquid methyl bromide. Toxicity of the gas has been underestimated owing to ignorance of its toxicity when used as a fumigant as well as its lack of odour at the lower concentrations and the fact that it possesses no irritant properties. Although the gas is less deadly to man than certain other fumigants in common use in countries like the U. S. A. it has been found that careless handling and inadequate protective measures will unduly expose fumigators and other persons coming in contact with the fumigant. It is therefore recommended that all the precautionary measures issued in connection with the use of the gas should be closely adhered to.

The Division of Industrial Hygiene of the National Institute of Health, U. S. Public Health Service in 1938 made the following preliminary recommendations :

1. Avoid breathing air containing methyl bromide.
2. On completion of fumigation, provide thorough ventilation for cars, rooms or buildings before entering.
3. When necessary to enter space containing methyl bromide, use a gas mask provided with a canister giving protection against organic vapours, or a positive pressure hose mask (masks and canisters to be approved under the U. S. Bureau of Mines Schedules 14 D or 19 A. Canister black, type B).
4. Avoid spilling of methyl bromide. Get to fresh air immediately in case of spillage. Remove any clothing in contact with the skin which has become impregnated with the liquid.

5. Post warning signs, notifying that methyl bromide is being used and that the gas is toxic.
6. Containers of methyl bromide should be stored in a cool, well-ventilated place, outside inhabited buildings. Avoid leakage by seeing that valves of cylinders are tightly closed.

Contact of liquid methyl bromide or high concentrations of its vapour with the skin may lead to the formation of blisters, or an eczematous skin. The parts which have come in contact with methyl bromide should be thoroughly washed immediately with plain water or preferably water to which a little washing soda is added. If blisters have appeared they should be dressed with propamidine cream or with 2 per cent tannic acid in triple dye solution. They can also be covered with a mixture of sulphathiazole, magnesium oxide and calcium penicillin under tulle gas. Chlorbutal ointment may be used to relieve pain.

In cases of systematic poisoning medical aid should be arranged. The first aid kit recommended in England includes oxygen-carbon dioxide reviving apparatus and Leptazol ampoules with injection equipment. According to published literature adrenaline should not be administered; ammonium carbonate may be given in the hope of decelarating vascular damage ; the carrying out of lumbar puncture is suggested as an aid to diagnosis.

Below is a list of commodities and the dosage of methyl bromide for fumigating them as successfully used in the U. S. A. at approximately 70°F. in shade. At temperatures about 80°F. on commodities easily penetrated, the time of exposure may be decreased proportionately. Much work has to be done in India on various commodities that require fumigation.

TABLE I

List of commodities treated with methyl bromide in the U. S. A.

Commodities treated	Method of treatment	Pounds per 1000 c.ft.	Time of exposure	Remarks
Dried beans and peas	Atmospheric	1·0 to 1·5	15 to 24 hours	
Dates (loose)	Atmospheric	1·0 to 1·5	15 to 24 hours	
Dates (compress packed)	Vacuum 25 in. to 29 in. sustained	2·0 to 3·0	1·5 to 3·0 hours	
Dried fruits	Atmospheric	1·0 to 1·5	15 to 24 hours	
Hay (baled)	Atmospheric	2·0	12 to 24 hours	
Nuts (whole or shelled)	Atmospheric vacuum 25 to 29 in. sustained	1·0 to 1·5 2·0 to 3·0	15 to 24 hours 1·5 to 3·0 hours	

TABLE I—*contd.*

List of commodities treated with methyl bromide in the U. S. A.

Commodities treated	Method of treatment	Pounds per 1000 c.ft.	Time of exposure	Remarks
Packaged foods, flour, cereals, spices, etc.	Atmospheric vacuum 25 to 29 in. sustained	1·0 to 1·5 2·0 to 3·0	15 to 24 hours 1·5 to 3·0 hours	
Plants and dormant nursery stock	Atmospheric vacuum	0·5 to 2·0 2·0 to 3·0	2·0 to 8·0 hours 1·5 to 3·0 hours	Must be varied according to the pest and host
Potatoes, tomatoes, pears, apples and green vegetables in general	Atmospheric	2·0	2·0 hours	
Potatoes	Vacuum 27 in.	2·0 to 3·0	1·5 hours.	
Textiles, bedding, furniture, etc.	Atmospheric vacuum 25 to 29 in. sustained	1·0 to 1·5 2·0 to 3·0	15 to 24 hours 1·5 to 3·0 hours	Rubber or rubberized materials should not be fumigated with methyl bromide
Wheat, rice, barley, corn and seeds in general	Atmospheric	1·0 to 1·5	12 to 24 hours	Methyl bromide has no deleterious effect on germination when used under normal conditions
Coffee (dried)	Atmospheric	1·5	12 hours	
Bagged grain like rice or other commodity of similar particle size	Atmospheric	3 2 1	4 hours 6 hours 12 hours	
Flour and returned flour bags	Atmospheric	1 1·25 2	24 hours 18 hours 12 hours	1·25 lb. for 18 hours is considered optimum

Ethylene oxide

Ethylene oxide is a colourless liquid at low temperatures. It boils at 10·7°C., has a specific gravity of 0·887 at 4°—7°C., molecular weight 44·031 and vapour pressure at 0°C., 493·1 mm. Its freezing point is 140°C. At 77°F. 112·5 pounds of the gas are required to saturate the atmosphere of 1000 cubic feet of space. At ordinary temperature it is a gas which is 1½ times as heavy as air. It has a rather faint odour suggestive of ether. It is inflammable in concentrations between 3 per cent and 80 per cent. But due to its excellent toxicity to insects particularly those attacking stored grain, the ease with which it can be handled, and the fact that it

leaves no odour or undesirable residue on foodstuffs, its use has been quickly adopted for the fumigation of several commodities. Moreover by mixing carbon dioxide with ethylene oxide, the insecticidal action of the gas is increased while the fire hazard is reduced. It is therefore now marketed in the U. S. A. as a mixture of one part of ethylene oxide to nine parts of carbon dioxide in steel cylinders for use in atmospheric as well as vacuum fumigation. It is available under various names like Carboxide, Guaradite gas; etc. and is supplied in 60 lb. cylinders under lb. per sq. inch pressure. In Germany a similar mixture is marketed under the name 'Cartox'. Although in actual practice it has been found that it is sufficient to use mixture of ethylene oxide and carbon dioxide at rates not higher than 1 : 10 —1 : 15 but not less than 1 : 7·5 in view of the inflammability of the ethylene oxide, in England and Germany, mixtures composed in the proportion of 90 per cent ethylene oxide and 10 per cent carbon dioxide are also used. In Germany such a mixture is called the T-gas and in England it is sold commercially in steel cylinders under the name of 'Etox'. It is diffused by means of flexible copper tubes through a fine jet. On exposure to air, ethylene oxide vaporises with rapidity. Even at low temperatures it can be used successfully on account of its low boiling point. It readily mixes with water, alcohol, acids and ammonia. It is less toxic than hydrogen cyanide but more toxic than carbon tetrachloride or sulphur dioxide being 250 times more toxic than the latter substance. Its insecticidal action is similar to that of methyl bromide. It has a delayed killing effect, is highly effective against insects eggs and about the same relative toxicity to insects in the adult stage. The post-fumigation effect of the mixture of ethylene oxide and carbon dioxide has however been found to be less than that of HCN in the case of Tobacco beetle. It will not bleach materials and is highly penetrative.

In spite of its efficiency as a fumigant, the cost of transporting the heavy cylinders of the gas makes it difficult to compete against some of the other effective fumigants like methyl bromide. Its manufacture has, therefore, been considerably reduced.

Directions for applying ethylene oxide. The fumigating chamber is at first loaded and made ready for fumigation. If small quantities of the liquid are to be used they can be drawn off by gravity flow into a tall glass jar, weighed or measured as is considered necessary and then poured directly into a shallow pan placed in the fumigating chamber. As the liquid is highly volatile at ordinary temperatures, its handling when transferring it into the pan should be done with speed. When large quantities of the liquid ethylene oxide are used for commercial fumigation, the required amount of the liquid should be first drawn into a graduated applicator similar to the one described for methyl bromide. The applicator is connected with the chamber by means of a metal tubing so that by opening a valve the measured quantity of the liquid is allowed to be drawn into the fumigation chamber. The temperature of the material to be fumigated should be between 75° to 78°F. In vacuum fumigation, when the ethylene oxide and carbon dioxide mixture like 'Guardite gas' is used, it is expanded to 75 lb. per square inch pressure in an

accumulator and heated to 120°F. to insure its entering the treating chamber in gaseous form.

Fumigation of grain. The most important use of the gas is for fumigating grain in bins. For this ethylene oxide mixed with solid carbon dioxide in the form of 'dry ice' can be used effectively although the process is expensive and laborious. Three pounds of liquid ethylene oxide and 30 pounds of carbon dioxide per 1000 bushels of grain are used. The mixture of the chemicals is made in the following way. The solid carbon dioxide is placed into an open end box and broken into small pieces with a sledge spade or ice pick. Ethylene oxide is then poured over the dry ice pieces in the proportion of 1 pound to each 10 lb. of the solid carbon dioxide. For quickly measuring out the required quantity of the liquid ethylene oxide, the cylinder can be weighed on a platform scale and the liquid forced out by air pressure created by a cycle pump. The mixture has to be stirred well so that the 'dry ice' takes up all the liquid. The mixture moreover has to be prepared just before use and taken to the bin floor where it should be immediately applied by shovelling into the grain stream as it is entering the bin. The mixture of the chemicals then becomes thoroughly distributed and mixed with the grain and soon changes to a vapour killing all insects which are present. In the U. S. A. to counteract leakage the dosage for the first 1,000 and the last 500 bushels is made proportionately greater and that for the rest of the grain reduced, so that the average of 33 lb. per 1,000 bushels is preserved.

According to the method adopted in the U. S. A. for bin fumigation, the person applying the fumigant will naturally have to inhale the gas, smaller quantities of which are not harmful. Prolonged exposure to the fumes should however be avoided as it is likely to cause severe nausea.

In Germany 'Cartox' is widely used for fumigating grain silos. The gas is however supplied only to authorized persons and is delivered compressed in cylinders of about 55 lb. capacity. Equipment is provided for air to be extracted at the top of the silo, mixed with the fumigant released from the cylinder and then blown into the bottom of the silo so that it passes upwards through the grain. On an average 18 oz. of 'Cartox' have to be used per ton of grain.

In the U. S. A. a dosage of 1 lb. per 1000 c.ft. for 20 hours has proved 100 per cent lethal to the Rice weevil (*Sitophilus oryza*) the Indian meal moth (*Plodia interpunctella*), the Saw toothed grain beetle (*Oryzaephilus surinamensis*) and the flour beetle (*Tribolium confusum*). But for commercial fumigation of warehouses the fumigant should be used at the rate of 2 lb. per 1,000 c.ft. of space.

In England for warehouse fumigation, the normal dosage of 'Etox' used is 10 to 12 oz. per 1,000 c.ft. for 24 hours. In the case of densely packed grain, larger quantities will have to be used.

Rice can be treated with ethylene oxide either in bulk, in sacks or in sealed cartons. As rice does not absorb much of the gas, comparatively small amounts of the fumigant are effective against the insects that attack it. Fumigation of bulk rice is easier than rice in sacks and specially the cartons as more gas will be required to penetrate the tightly sealed cartons. As in India rice is generally kept in sacks

or in straw packing, its fumigation is not difficult, disinfestation being possible using one lb. of ethylene oxide per 1,000 c.ft. of space during overnight fumigation in atmospheric fumigation chambers. In vacuum fumigation, ethylene oxide should be used in the proportion of three pounds per 1,000 c.ft. for one hour, or pounds per 1,000 c.ft. for two hours. When used in combination with carbon dioxide, 2 lb. of ethylene oxide per 1,000 c.ft. for ½ hour. or 1 lb. per 1,000 c.ft. for ¾ hour, is sufficient for the treatment of bulk rice. Vacuum fumigation of bulk rice can be done in special chambers set on the end. The rice can be run into the chamber at the top and after fumigation it is drawn off through a valve at the bottom. The use of this method considerably reduces the cost of handling.

Dried beans of all kinds either loose or in bags can be fumigated with ethylene oxide. In atmospheric fumigation 2 lb. of ethylene oxide per 1,000 c.ft. of space, for an overnight exposure will kill all weevils present whether the beans are in bags or in bulk and in vaccuum fumigation 3 lb. of ethylene oxide alone per 1,000 c.ft. for one hour, or 2 lb. of ethylene oxide per 1,000 c.ft. for two hours will give a perfect kill. In combination with CO_2 it would be necessary to use 2 lb. per 1,000 c.ft. for ½ hour or 1 lb. per 1000 c.ft. for one hour.

Fumigation of barges with ethylene oxide. Fumigation of dried fruit arriving at a sea port can be conveniently carried out in steel barges using ethylene oxide as the fumigant. To enable proper distribution of the gas, the stacking of the fruit boxes should be carefully done. They should be placed in sing tiers two to three inches apart and run transversely across the barge. The boxes should not be stacked nearer than 15 inches to the hatch covers. An open passage about 4 ft. wide should be left running along the centre of the barge to within three or four tiers of the ends. Every box must have its two ends exposed to the free space. The hatches must then be closed by its wooden covers and these in turn covered by heavy tarpaulins. The edges of the latter will then have to be clamped to the hatch coamings by means of battens wedged in cleats. In barges which are kept in good condition, ordinarily the leakage can only be through the hatch openings. The application of the fumigant is done in the following manner. Ethylene oxide containing 10 per cent carbon dioxide in cylinders is used for this purpose. A copper pipe 3/8 inch in diameter from the cylinder valve has to be led into the barge and terminating in a T-piece, the two branches of which are about 15 in. long being directed one towards each end of the barge. The T-piece and its two branches will have to be raised on boxes about two feet above the boxes on each side of the passage. The exit ends of the two branches of the T-piece are fitted with nozzles through which the liquid is ejected as a fine spray under pressure from the cylinder. The fine spray is formed from two axially rotating jets which are ejected through an orifice of 0·05 inch in diameter. The nozzles will have to be dismantled, cleaned frequently and adjusted to deliver equal volumes of liquid at equal pressure. At temperatures below 50°F. a vaporiser has to be used but such a contingency rarely arises in India. The dose of the fumigant to be used assuming that it contains 85 per cent of ethylene oxide is calculated at the rate of 1 lb. for every 50 boxes of dry fruit being approximately 1¼ tons and 6·5 lb. per 1,000 c.ft. of free space. The fumigation should last 18 hours.

Fumigation of dried fruit. Dried fruit in bulk or in cartons can be fumigated easily with the gas using a dosage of one pound of ethylene oxide per 1,000 c.ft. for 12 hours in atmospheric fumigation in an airtight chamber. If the chamber is not quite airtight 2 pounds would have to be used per 1,000 c.ft. If vacuum fumigation is carried out, 2 lb. of ethylene oxide per 1,000 c.ft. for $1\frac{1}{2}$ hours, or 3 lb. per 1,000 c.ft. for one hour are sufficient to disinfest dried fruit both in bulk and when packaged. In combination with CO_2, 2 lb. per 1,000 c.ft. for $1\frac{1}{2}$ hours are sufficient.

Fumigation of nut meats. As nut meats like shelled, raw groundnuts, almonds, etc. absorb a much larger amount of gas than most other foodstuffs, a greater dosage would be necessary to destroy insects in them. A dosage of 3 lb. of ethylene oxide per 1,000 c.ft. for an overnight or 16 hour exposure would be required in atmospheric fumigation. If used in combination with CO_2 only, two pounds per 1,000 c.ft. are sufficient. In vacuum fumigation a dosage of 3 lb. of ethylene oxide per 1,000 c.ft. in combination with 28 lb. carbon dioxide is most suitable. For fumigation of nut meats the dosage is considered to be the best and effective.

Fumigation of fresh fruit and potatoes with ethylene oxide. This gas is reported to have been successfully used in the plant quarantine stations of France for fumigating fresh fruit particularly apples, against the introduction of the San Jose Scale. Fumigation for $1\frac{1}{2}$ to $2\frac{1}{2}$ hours with the gas at the rate of 100 gm. per c. m. (i.e., 10 oz. per 100 c.ft.) under a partial vacuum of 50 mm. (1·97 in.) after an initial vacuum of 635 mm. (24·9 in.) has been found to be effective against San Jose Scale and other diaspine coccids on apples without injuring the fruit under treatment. Effective control of larvae and adults of *Leptinotarsa decemlineata* Say (Colorado potato beetle) was also obtained by fumigation of infested potatoes using 30 gm. per c.m. for an hour under vacuum of 50 mm. But work carried out in other countries has shown that the gas is injurious to fresh fruit, in some cases rotting commencing about 10 days after fumigation. The use of methyl bromide has therefore now practically replaced the use of this gas. In India ethylene oxide has therefore to be used with great caution for fumigating fresh fruit and potatoes and better be avoided. It can however be used for fumigating dried vegetables. The dosage is 120 gm. per c. m. for two hours or for six hours with 100 gm. in a vacuum of 60 mm. (2·36 in.) with an initial vacuum of 700 mm. (27·56 in.).

Fumigation of books and records. Ethylene oxide has been used with great success against insects attacking books, valuable records and documents. The gas is used in all the libraries and National Archives in several countries. Ethylene oxide and carbon dioxide mixture and vacuum method of fumigation is made use of in all such cases. The books, records, etc. are placed in a vacuum chamber and the air in the latter is evacuated till the vacuum gauge registers 29·9 inches of vacuum. The gas is then introduced and the vacuum is allowed to fall to 21 inches. The exposure period should be three hours.

Precautions. As ordinarily used, the danger to human beings and higher animal from breaking vapours of ethylene oxide is not great, it being less harmful than fumes of hydrochloric acid and sulphur dioxide, more harmful than chloroform and

carbon tetrachloride but all the same precautions have to be taken against breathing of the gas as in the case of any other dangerous gas. It does not possess enough odour to warn of high concentrations but causes intolerable irritation to the eyes and nose when present in high concentrations. Even in comparatively safe concentrations it causes although moderate, distinct irritation which must be taken as a warning to avoid serious injury. In the case of guinea pigs, exposure to the gas has resulted in irritation of the respiratory system sometimes resulting in pneumonia. In man, prolonged exposure causes a form of cyanosis which can be counteracted by administration of carbon dioxide gas. Grains fumigated with ethylene oxide do not lose their milling or baking qualities but their germinating power is destroyed. *It should not therefore be used for fumigating seeds intended for germination. The gas should also not be used for fumigating live plants.* As mixtures of ethylene oxide and carbon dioxide contain large percentage of the latter gas which when released in the air decreases percentage of oxygen below the safety limits resulting in suffocation and rapid breathing, the use of a gas mask and canister at fumigation doses is precluded, although these could be used to enter the structure during the aeration process. A respirator fitted with the appropriate filter should be worn by operators using 'Etox'. In England 'Degea' mask with initial 'A' and having a brown filter specially manufactured for use with 'Etox' is used. Ordinary rooms fumigated with the T- gas should be ventilated for at least 20 hours and trade premises for at least 12 hours after fumigation. If the fumigation period is 24 hours or less and a very exact determination of the gas residue is made before the use of the premises is permitted, a ventilation period of six hours may suffice. T-gas should not be used in the presence of naked lights owing to the risk of fire or explosion, the lower limit for the latter being a mixture of air with 3·6-3·7 per cent T-gas. When the T- gas is used for fumigating rooms, all heating devices should be removed prior to fumigation and ashes in fireplaces have to be drenched with water.

Fumigation chambers

As the fumigants can act best and without any risk only in tight enclosures, the construction of fumigation chambers requires considerable care. They are an important part of every plant quarantine station. Ordinarily all modern plant quarantine stations must be provided with vacuum fumigation chambers which can also be used for ordinary atmospheric fumigation. Separate chambers for atmospheric fumigation may also be used.

Whatever type of fumigation chamber is used, experience of nearly 25 years with fumigation of nursery stock, seeds, grain and other agricultural produce in other countries indicates that if a treatment is to be used to alleviate quarantine rejection and kill completely the insects in the commodity, all possible factors which influence its effectiveness must be under the control of the operator. The chamber has therefore to be (i) constructed in such a manner as to permit no leaks ; (ii) insulated to avoid temperature fluctuations ; (iii) equipped with proper accessories for measuring the fumigant ; (iv) equipped with heaters to permit temperature control ; (v) equipped with means of noting the inside temperature at all times from the outside and (vi) equipped with a humidifier for use when necessary.

Atmospheric fumigation chamber

The simplest type of fumigation chamber consists of a gas tight room and door. Inexpensive chambers can be made of sheet metal or plywood, their construction being altered to suit the conditions under which they are to be used. All such chambers should be also provided with an exhaust blower and shut-off valve to dispel the gas completely after fumigation. This is popularly called an atmospheric fumigation chamber because the fumigation is performed under ordinary atmospheric pressure. The size of the chamber varies to suit particular requirements. The floor may preferably be made up of good grade 1×8 tongue and groove, studding and rafters being 2×45 set 22 inches apart, sheathed inside with 1×8 tongue and groove, outside with a good plaster board material. The space between sheathing should be filled with ground cork for heat insulation only if chamber is exposed to low temperatures. The inside of the chamber is lined with a good roofing tin with soldered seams. Over the tin floor a latticed platform made in sections (so as to be easily removed for cleaning the floor) should be laid for protection and so that the load to be fumigated is raised off the floor, allowing the gas to get under it. The most important part of a chamber is a gas tight door. It should be about 4 ft.× 6 ft. in the case of large chambers and be provided with a sponge rubber gasket. For usual conditions in a chamber of 1,000 c. ft. capacity the utility blower No. $1\frac{1}{4}$ with $7\frac{1}{2}$ in. outlet and inlet placed preferably at the posterior end will suffice. The blower case will have to be made air tight by means of a gasket in the casing joint and packing around the fan shaft where it passes through the casing. The temperature of the material to be fumigated should be above 70°F., throughout the period of exposure to HCN or methyl bromide gas. In places where the temperature of the room and the material to be fumigated are below 70°F. a sheathed chamber with heating means is provided in a fumigation chamber and the material allowed to remain in the chamber prior to fumigation until it is above 70°F. Where the temperature of the material and the room containing the chamber as is usual in India above 70°F. no insulation, outside sheathing or a heating means will be required. However, when necessary as a source of heat, steam or hot water are satisfactory and for this purpose a pipe of sufficient radiation capacity must be run into and around the chamber as near to the floor as possible. Electric heaters of the exposed fire type should not be used, as this would change methyl bromide to hydrobromic acid which is injurious to commodities and equipment. A standard hot water radiator equipped with electric bayonet heaters and thermostatically controlled so as to maintain the chamber at the required temperature is the most suitable one. A brass marine port light with an opening of six inches should be installed on one side near the door about 5 ft. 6 in. above the floor and a thermometer located in the inside of the chamber in front of the port light so that temperature can readily be read from outside. A small electric fan with explosion proof motor should be located on a shelf preferably at the upper left hand corner of the chamber, near the door. This is to circulate the gas. Wiring switches, etc. for blower fan, and light and the control for heat should be located outside of the chamber. All wiring should be run from switch box into vault through one or more 'L' shaped conduits having their inside opening pointed upward. After the wiring, etc. has been permanently fitted

up, paraffin with a high melting point or any other similar material should be poured into the 'L' tube to seal it off thoroughly.

An improved atmospheric chamber with circulatory system of approximately 1,000 c.ft. capacity can also be constructed. After the gas has been introduced into the chamber, the blower is started and with the proper valves opened a continuous and thorough agitation of the gas mixture is affected throughout the chamber. The advantages of such systematic agitation are (i) that it ensures rapid penetration of the gas into the material to be fumigated, thereby killing the insects imbedded in it and shortening the period of exposurs considerably and (ii) that it greatly accelerates ventilation of the chambers and removal of the last traces of the gas, thereby making it possible to remove the fumigated material from the chamber in much shorter time.

Methods of loading and operation of chambers. The commodity to be fumigated should be stacked in criss-cross fashion in a number of rows with a few inches of space between the rows. A few inches of space between the walls of the chamber all round and the commodity should be left. An air space of three or four feet should also be left at the top of the chamber above the commodity. This arrangement allows the gas to circulate and penetrate properly.

After the material to be fumigated is loaded in the chamber and if the temperature in the chamber is below 70°F., heat is turned on till the temperature comes to this level. The port light is closed and the blast gates on blowers are closed by closing valve over blower. An inspection of these is very essential. The chamber door is closed and tightened by means of the clamps, then locked. The electric fan is next turned on at low speed. Both valves in ducts should be opened and valve in discharge line to atmosphere closed. Blower is then turned on and operated at half speed for two to four hours. When liquid HCN or methyl bromide is used in atmospheric fumigation the dosage is measured by placing the cylinder on a portable platform scale, located along side the chamber. The scale beam is set for the required dosage, the liquid HCN or methyl bromide discharged into the chamber and when the scale beam tips, the cylinder valve is closed. In the case of HCN after the required dosage has been discharged into the fumigation chambers it is necessary to blow out the gas remaining in the hose and piping and also to release the air pressure in the cylinder.

Opening chamber. When the exposure period is completed, exhaust valve is opened, and exhaust fan started. In the case of improved chamber circulation system, all ducts and discharge valve to atmosphere and the byepass valve should be opened and the fan started. The port light is opened to admit air to chamber. When the blower has run for about 15 minutes at full speed the chamber door is opened by about an inch and blower is kept running for about 15 to 20 minutes, then the chamber door is opened and the objects or material treated are removed. Electric fan is then turned off and lastly heat if used and the blower are turned off and all the valves are closed.

To avoid confusion in valve operation the discharge valve to chamber which is the master valve for discharge to chamber should be painted with a distinctive colour. It must be remembered that when the discharge valve to chamber is opened for circulation the other valves i.e., the discharge valve to atmosphere and the bye-pass valve should be closed while for the venting period, it is *vica versa*.

Vacuum fumigation chamber

A vacuum fumigation chamber is a gas tight steel chamber with a tight sealing door and is equipped with a vacuum pump to exhaust all the air from the material under fumigation. This is of special advantage where time is an important point for consideration. In atmospheric fumigation particularly when using HCN gas it has been found that penetration of the gas is slow and limited. This is specially so when tightly packed material or plant material with insects deeply imbedded in plant tissues have to be fumigated. Thirty inches of mercury on a gauge represents complete vacuum at sea level. In vacuum fumigation, the air from the fumigation chamber is pumped out until a vacuum of 28½ in. of mercury is indicated on the gauge. The exhaustion of air from the chamber will also remove the air from within the commodities in whatever type of container they are placed in. Vacuum chamber is provided with HCN volatilizer for introducing the required dosage of liquid HCN from a cylinder into the chamber. After the air has been exhausted, the HCN gas which is admitted immediately fills the space previously occupied by the air, thus forcing the fumigant through the material under fumigation.

The gas is allowed to remain in the chamber under vacuum for the period of time necessary to kill the insects in the commodity under fumigation. At the end of the fumigation period, the gas is withdrawn from the chamber by means of the vacuum pump. Air is then allowed to enter the chamber until normal atmospheric pressure is reached. The admixture of the remaining gas and air is again evacuated. Later fresh air is again allowed to enter the chamber. This procedure which is known as 'Air washing' removes any residual gas from the chamber. Vacuum fumigation chambers are equipped with exhaust fans to shorten the time of air washing. The use of this fan in operation, clears the chamber of residual gas in a very few minutes making it possible for workmen to start unloading the chamber immediately after the vacuum in the chamber is broken. The fan should be kept running during the entire period of unloading.

Vacuum fumigation chambers can be constructed to any size, according to individual requirements depending upon the maximum amount of commodity which has to be fumigated in a particular period of time at each loading. They may be installed singly or as dual units (Plate V, fig. 8) either rectangular or circular in shape with doors swung on Jib cranes or on hinges. They may have doors at both ends or only at one end. The present tendency in most countries is to have chambers with doors at both ends to expedite simultaneous loading and unloading of goods placed in truck trains. Also so that there is no wastage of space, rectangular chambers are preferred. Vacuum pumps of the chambers are ordinarily of the horizontal piston type guaranteed to evacuate to required vacuum in specified time. They may be driven by electric motor, gasolene or steam engine.

Vacuum fumigation ensures proper penetration of the gas and is the most suitable method for use when closely packed material, like bales of cotton, or hogs heads of tobacco are to be fumigated and the exposure required for vacuum fumigation is about one tenth the time required for atmospheric fumigation. During vacuum fumigation, the fumigated commodity absorbs large quantity of the fumigant. This brings the gas into direct contact with the insects and their eggs which may be deeply placed in the commodity, plant material or plant product. 'Post fumigation' effect while using HCN and methyl bromide gas in vacuum chambers is also considered by some to be an important feature because during the period the gas is being given off from the fumigated material it continues to function in killing any insects or destroying any eggs which may have escaped being killed during the process of fumigation in the chamber. All materials fumigated under vacuum should be allowed to aerate in normal storage for at least 74 hours after fumigation.

When a chamber is first put into operation, the aeration time should be checked at the completion of several fumigations. When methyl bromide is used, this checking is done through the use of a halide leak detector torch. After several such checks with the torch, a minimum aeration period should be set up for the chamber which allows for a reasonable safety period. When HCN is used for fumigation, its presence can be tested with the help of methyl orange test papers.

Other methods of disinfestation

Hot water treatment

This treatment can be used for narcissus bulbs infested with bulb flies and is given in large tanks about 3 to 4 feet high (Plate VI, fig. 9). The bulbs are placed in a rectangular wire bag and lowered into the tank with the hot water. A presoak treatment for two hours in the hot water at 75°F. is first given. The material is then kept between 110°F. for 4½ hours. The hot water has to be kept stirred up during treatment by means of special rollers at the bottom of the tanks. But it can be done even by means of a long stick.

Hot water treatment can also be used against sugarcane borers in imported sugarcane.

Soil sterilisation

Under the Federal regulations, soil from foreign countries is not permitted entry in the U. S. A. If by any chance plant material is intercepted with soil, the latter is removed completely and sterilised in an autoclave. The temperature has to be raised to 129°F. at 15 lb. pressure for half an hour. A similar procedure in India would be necessary to prevent soil bacteria, insects and nematodes entering this country.

Refrigeration

In the case of certain fruit pests like the Mediterranean fruit fly, it has been found that if the fruits are held at 31°F. for 11 days, all stages of the fly are killed

This method of disinfection is imposed as a quarantine requirement for fruit imported into the U. S. A. from the South America and the South Africa. The fruit is precooled at this temperature and then loaded in special refrigerator ships. This temperature, i.e., 31°F. is kept up during the voyage. Automatic temperature recorders which keep an exact record of temperature of the refrigerators are examined on arrival at the port of entry in the U. S. A. The other recommended refrigeration treatments against the Mediterranean fruit fly in fruit are 13 days at 33°F., 14 days at 34°F., 16 days at 36°F. and against *Bactrocera cucurbitae* for 15 days at 35°F.

Oil dip

Dipping of insect infested nursery stock and fruit in oil emulsion is prescribed in connection with some plant quarantine regulations. This method is only suitable for insect pests on the outside of the plant material or fruit and is adopted in California for imported citrus fruit and balled citrus stock.

In the case of fruit like Mexican limes and other approved sour limes complete submersion for a period of not less than 5 minutes in a 3 per cent concentration of an oil emulsion of the mayonnaise type (the stock emulsion of which shall contain not less than 80 per cent oil by volume of an oil that shall test not less than 65 viscosity seconds saybolt and not less than 90 unsulphonated residue) is carried out. Apparatus used for this treatment is a large vat so constructed as to permit complete submersion of the fruit and is equipped with an agitator that will insure a dipping medium of uniform consistency throughout. The emulsion is heated and kept at a temperature between 50°F. and 100°F. during time of treatment. Dipping tank has to be completely drained and cleaned and new dip of fresh ingredients prepared if it becomes fouled with debris. In the case of hard water, softener has to be used.

In the case of balled citrus the pest concerned is citrus bud mite, *Eriophyes sheldoni*. The pre-treatment requirement for this is that the dipping vat must be of an approved type with proper facilities for agitation of solution and having a minimum capacity of 75 gallons. Treatment requirements are that the oil must be of an emulsive type with viscosity from 60 to 70 seconds saybolt and having an unsulphonated residue test of 90 or above. Use emulsion at rate of 10 qt. to make 75 gallons dipping solution. All parts of foliage, branches and trunk must be immersed and withdrawn twice.

After treatment the trees are kept in a vertical position in a location free from wind and direct sunlight for a period of 48 hours.

Superheating and team sterilization

High temperatures for disinfection of plant material, plant products, grain and seeds are used in certain cases in connection with quarantine work. These high temperatures may be applied directly in chambers or by steam sterilisation.

For example U. S. Federal regulations against the spread of pink bollworm requires certification for inter-state movement of cotton seed. These certificates

are issued only to approved gins in lightly infested area if the seed has been heated to a temperature of 150°F. for a minimum period of 30 seconds as a part of the continuous process of ginning under the supervision of a quarantine inspector and subsequently protected from contamination. In the case of inter-state movement of cotton seed originating in heavily infested areas, limited permits are issued for inter-state movement of cotton seed after the seed has been treated under supervision of a plant quarantine inspector and when it is consigned only to contiguous lightly infested areas for processing therein in an oil mill authorized by the Chief of the Bureau of Entomology and Quarantine under the following conditions. When the seed has been treated and protected as mentioned above and (*a*) when given a second heat treatment at a temperature of 155 F. for a minimum period of 60 seconds under the supervision of an inspector at a plant operated separate and apart from the gin or gins which applied the initial treatment as a part of the continuous process of ginning or (*b*) when the seed is given, under the supervision of a plant quarantine inspector the foregoing second heat treatment at the designated oil mill on arrival. The carriages or any other vehicles conveying the seed to the designated oil mills are also required to be cleaned and sterilized under the supervision of an inspector, immediately after unloading.

A number of cotton seed sterilizers have been developed in the U. S. A. Some of the important types are (i) Gas-heated revolving Drum Steriliser, (ii) Jacketed Conveyers Trough Steriliser, (iii) Brookfield Improved Steam Steriliser, (iv) Brookfield Gas-heated Type Steriliser, (v) Wellcasing Steam Jacketed Type, (vi) Three-Tier Type and (vii) Vertical Steriliser and Heater. Various kinds of superheaters for drying the steam have also been developed. The most important part of these sterilisers is the series of 10-feet sections of jacketed conveyer troughs, all connected so as to make one continuous trough of a length required for heating the cotton seed. Perforated steam pipes extending the entire length of these troughs are mounted inside the trough just above the path of the seed which is moved forward by a conveyer screw. The intake steam pipes are connected to the steam pipe from the boiler and so the live steam from the perforations gets directly ejected into the moving seed. A thermo-graph bulb is installed within a plain conveyer trough about the middle of its length to record the temperature of the seed. The ginners prefer a machine to give the seed a thorough drying and at the same time allow to run the conveyer screw at a reasonably rapid rate.

In the case of ears of corn one of the approved methods of disinfection against the European corn borer is their heating in a chamber at an air temperature of not less than 168°F. for a period of not less than two hours. The ears of corn have to be spread out not more than one layer deep on slat or wire shelves in the chamber and the time of sterilization shall begin when all thermometers reach 168°F. after corn has been placed in the chamber.

In the case of broom corn and articles made of broom corn, steam sterilization under vacuum is prescribed. Air pressure in the chamber is reduced to 25 in. vacuum at first. Then steam is introduced until positive pressure of 10 lb. is

obtained. This pressure has to be sustained until constant temperature in all parts of the chamber is attained.

Live steam sterilization of railway carriages is also an approved method for disinfecting carriages infested with cotton seed having pests. The carriages have to be made reasonably tight and the steam let into directly from the boiler until the seed is softened. Fumigation with HCN being more effective and certain, has replaced this method.

In the case of fruit and vegetables, vapour heat treatment is prescribed. Heating has to be for a period of not less than 14 hours during which time the temperature at the approximate centre of the fruit should be 110°F. and maintained at this temperature for eight hours of such treatment. This treatment is prescribed against the introduction of Mexican fruit fly. The steam has to be applied in such a manner as to secure uniform distribution of the heated air and so that it does not discharge directly on the fruits.

Introduction of steam into vacuum tanks used for fumigation and maintaining a temperature of 122°F. for three minutes has been found to kill several species of insects infesting cereal products including the resistant eggs of *Tribolium confusum*. Fumigation using methyl bromide has replaced this method completely.

Thermal vacuum process using a vacuum chamber can be used against pests of tobacco. In using this treatment the hogsheads are placed in the chamber and the air exhausted till a vacuum of 29·5 inches is registered. This vacuum is held for five minutes. Live steam at a temperature of approximately 300°F. and a pressure of 95 pounds is slowly admitted until the vacuum within the chamber is reduced to about 18·5 inches. The chamber is then again evacuated to a reading of approximately 27·2 in. and this vacuum is held for three minutes after which it is released. The chamber is then opened and the hogsheads are reRoved.

Used bags and returned products can be sterilized by placing them in a heating chamber or vault made of bricks or concrete designed to avoid loss of heat. A small unit heater can be employed; otherwise wall radiation of 20 sq. ft. per 100 cubic feet of vault-space would be sufficient to provide the required amount of heat. The vault should have a false or raised floor to permit circulation of hot air under the materials to be heated and built-in racks for separating bags of flour, etc. and to enable heat to penetrate milled cereals properly. When wall radiation is used, to prevent stratification of the heated air and for circulating it thoroughly, a fan designed for operation in high temperature must be provided inside the vault. Using a steam pressure of, from 50 to 75 pounds a temperature up to 200°F. can be quickly obtained and maintained. With these vaults at temperatures between 180° and 200°F., bags of flour, etc. can be completely freed from insect life in 24 hours.

DISINFESTATION AT AIRPORTS

Disinfection of airports

Rapid development of air transportation has brought us much closer to the insect pests of foreign countries. In spite of regulations preventing passengers in

planes bringing plant material, thousands of interceptions of insects are being made in cargo shipments, passengers' baggage and parcel post and as stowaways in various countries. Insect aliens coming as stowaways in airplanes are very dangerous and present a serious international problem. Some of these insects may even be vectors of plant diseases. The insect problem as applied to airplanes is therefore an international problem and India must take due recognition of it.

There must therefore be rigid control of insects, specially the economic pests—breeding on and near all places where aircraft may be parked. Cultivation of crops on or in the vicinity of airports should be prohibited as such cultivated areas can serve as centres of infection. Any miscellaneous vegetation forming a thick area of plant cover should also be removed and grass on airfields should be always kept closely mowed. All airports should also receive special regular insecticidal treatments by spraying with D. D. T. or other insecticidal solutions or suspensions. For this in the U. S. A. the liaison type of aircraft like L-5 is fitted up with aerial spraying appratus. This must be made available in all Indian air ports. Parked aircraft especially those in transit should be located as far as possible away from all areas of vegetation preferably on wide concrete aprons in front of hangers and operations building. Parked aircraft should be as much as possible kept closed up. Parked aircraft should never be left at night with the interior lights burning, specially if the doors and other openings are not tightly closed.

Disinsectization of foreign aircraft

The Quarantine Inspector must be at the side of the aircraft with spraying equipment as soon as the plane arrives and stops on the airfield. Immediately upon arrival, data concerning the time and method of disinsectization should be obtained from the flight personnel. If the plane has not been sprayed in flight in accordance with regulations, all openings must remain completely closed except to admit the inspector and the plane sprayed immediately with passengers and crew aboard. All baggage compartments accessible from outside the plane should also be sprayed immediately. Flight personnel should not be allowed to leave the plane until the disinsectization process is completed. If certain officials are given permission to board before the plane is released from quarantine, all such persons must remain within the plane until disinsectization is completed. The inspector must see that all windows and other openings are securely closed and that no spray is released until the plane is completely closed. He must work rapidly, opening interior compartments as he walks forward and great care must be exercised by him to insure a thorough and even distribution of aerosol spray throughout the aircraft. Interior compartment doors should be kept closed, each compartment being sprayed separately. Trap doors, cabinet and cupboard doors, tops of storage boxes should be opened so that the spray can penetrate into all potential insect hiding places. He must take care to conscientiously direct the spray into all semi-closed spaces such as under seats, behind the instruments, tanks and apparatus where insects may remain hidden. All spaces behind and between cargo and baggage are especially important and should have the spray deliberately directed into them. The proper amount of

insecticide to be dispensed has to be determined by knowing the cubic contents of the aircraft. When using the American military type of aerosol bomb, the dosage recommended on the bomb should be doubled. Ordinarily in such cases the spraying time must be 16 seconds per 1,000 cubic feet of aircraft space.

Spraying time

Spraying time for aircraft in general use should be as follows:

	Seconds
DC-3 (C-47) Cabin	32
Baggage compartment	4
DC-4 (C-54) Cabin	48
Baggage compartment	8
DC-6 Cabin	80
Baggage compartment	8
Constellation—Cabin	70
Baggage compartment	8 each

The above figures are *minimum desirable.* The Quarantine Inspector must use his judgement in determining whether the plane is adequately sprayed after this time has elapsed. The above figures should also be revised according to the type of aerosol used in India. In California 'aerosol bombs' produced by Bridgeport Brass Co., are used for spraying. Their formula is D. D. T. 3 per cent, pyrethrins 0·4 per cent, hydrocarbon oil 1·6 per cent, polymerised naphthalene 15 per cent and Freon 80 per cent. The U. S. D. A. Aerosol formula is Freon 85 per cent, D. D. T. 3 per cent, cyclohexanone 5 per cent, pyrethrum 5 per cent and lubricating oil 2 per cent, this aerosol being used at the rate of 20 gm. for 1,000 c.ft. In Hawaii, to the U. S. A. formula is added Technical Chlordane (Velsicol 1068 or Octa-Klor). This has greatly increased the insecticidal value of the aerosol in killing insects often difficult to be killed like the large heavy bodied Hemiptera and Coleoptera.

Aircraft quarantine declarations which must be handed over to the Indian Quarantine Officer by the Aircraft Commander must be examined by the Plant Quarantine Inspector to see if any plant material or insects are manifested to be aboard the aircraft.

Disinsectization of aircraft before leaving an airport in India

Plant Quarantine Inspectors must inspect all baggage and commissary stores of a plane before departure. No unauthorised plant material other than fruits for consumption enroute should be permitted in a plane leaving India. Ministry of Agriculture Airplane clearance certificate should be issued to the Chief of flight staff of the plane.

After loading of fuel, baggage, cargo, passenger and crew and immediately prior to the warm up of the engines all parts of the plane must be sprayed with aerosol. During the process of disinsectization the engines should not be operating. With all doors, windows, hatches and other openings to the exterior closed, thorough spraying should be done in all the cabins, cockpit, baggage, cargo and other compartments and enclosed spaces. If any of these portions are inaccessible from within the plane, they must be sprayed when loading is completed. The plane must be certified in the clearance of the aircraft, as well as signalled to the control tower. Aircraft should not be cleared for take off until the disinsectization has been indicated to the control tower. Operation officer must maintain appropriate records.

APPENDIX I

Extract from Notification No. 13-c, dated the 7 November 1917, Government of India, Department of Agriculture and Revenue

Directions for fumigation of plants

1. Remove the covers of the cases, wrappings of packages, etc. and spread the plants out in the trays together with all moss, wrappings, etc. in or with which they have been packed, taking care that the contents of each package are kept separate. The plants should be spread out loosely so that the gas will be able to penetrate between the plants.

2. Close up the plant chamber, wedging the door or lid securely.

3. Place the vessel containing the requisite quantity of water in the small external gas generating chamber. Add the acid to the water : never pour the water into the acid or it will react violently and spatter about. Take the weighed quantity of cyanide, wrap it loosely in a piece of clean paper, drop it in the vessel of acid and water and immediately close and fasten the door of the generating chamber. Note the time.

Quantities of chemicals required :

For each fumigation Box (100 c.ft.)

Water	1 fluid oz.
Sulphuric acid	1 fluid oz.
Potassium cyanide (98 per cent)	$\frac{1}{2}$ oz.

For larger chambers. According to size, at the rate of :

Water	1 fluid oz.	per 100 c.ft. of internal capacity.
Sulphuric acid	1 fluid oz.	
Potassium cyanide (98 per cent)	$\frac{1}{2}$ oz.	

4. After three-quarters of an hour open the door or lid of the fumigated chamber or box taking care not to breathe any of the gas whilst doing so, and leave it open for at least a quarter of an hour before making any attempt to remove the plants. The trays may then be removed and the plants exposed to a current for air for another quarter of an hour after which they may be repacked.

NOTE.—In all cases when an agent of the consignee is in attendance, the unpacking and repacking of the plants will be done by such agent.

CAUTION

1. Living plants must not be watered immediately before fumigation, as wet foliage is liable to be injured by gas. If received wet, they should be allowed to dry before fumigation.

2. After fumigation, plants should be protected from the sun for several hours, preferably until the following morning. Do not, therefore, spread plants out in the sun's rays after fumigation to dissipate the gas.

3. Sulphuric acid is strongly corrosive and will burn into the skin, flesh, or clothing. If acid should accidentally be spilt on to the hands, plunge them immediately into a bucket full of water. If acid should be splashed on to the clothes, pour liquid ammonia on to the spot to neutralize the acid.

4. Potassium cyanide is a deadly poison if taken into the system, either if swallowed or introduced through any cut or wound in the skin. It is better, therefore, not to touch it with the bare hands but to wear gloves or to handle it with forceps.

5. Hydrocyanic acid gas, produced by the action of sulphuric acid on potassium cyanide is extremely poisonous if inhaled. It is colourless, non-inflammable and has a faint smell some thing like that of peachkernels or of some metals when these are struck together. Great care must be taken to avoid breathing in any of the gas before it has all escaped. Should symptoms of poisoning be noticed, the patient should be immediately removed and placed in the open air.

APPENDIX II

FIRST AID AND MEDICAL AID IN CASE OF ACCIDENTAL HCN POISONING*

In case of accidental HCN poisoning the unconscious man should not be rushed to the hospital as prompt action on the spot is essential. The patient must be carried to fresh air or to a room free from the gas and comfortably warm and made to lie down. First aid treatment should be immediately given and a doctor sent for at once. If the patient is conscious and breathing, an amyl nitrite pear should

*Adapted from Fumigation Manual by American Cyanamid Co.

be broken in a cloth and held lightly over the nose for 15 to 20 seconds. This should be repeated every 5 minutes for about 25 minutes if recovery is not seen. If the patient has stopped breathing, the patient should be given artificial respiration. If patient is unconscious but breathing, an amyl nitrite pearl should be broken in a cloth and held lightly over the nose for not more than 20 seconds repeating every five minutes for 25 minutes. The patient should also be given oxygen from an inhalator apparatus which all fumigatoria should be provided with. An unconscious person should not be given anything by the mouth. This is a very important point to be remembered. A person giving first aid should protect himself also with a gas mask if he has to get out a man from a space with HCN gas.

The first aid kit that must be available at all fumigatoria should consist of the following :

12 pearls of amyl nitrite

2 Ampoules of sodium nitrite

2 Ampoules of sodium thiosulphate

1 Sterile syringe 10 c.c.

1 Sterile syringe 50 c.c.

The kit must be ready for the doctor for use immediately he arrives on the scene. *The method of administering the antidote to be done only by the doctor* should be as follows. A trained assistant must be asked to break one at a time, pearls of amyl nitrite in a handkerchief and the latter held over the patient's nose for 15 to 30 seconds per minute. At the same time the doctor should quickly load his syringe one with a 3 per cent solution of sodium nitrite and the other with a 25 per cent solution of sodium thiosulphate. The administration of amyl nitrite should be stopped and 10 c.c. of the 3 per cent solution sodium nitrite should be injected intravenously at the rate of 2·5 to 5·0 c.c. per minute. Then with the same needle and vein or with a larger needle and new vein, 12·5 gm (50 c.c. of a 25 per cent solution) of sodium thiosulphate should be injected. The patient will subsequently have to be watched for 24 to 48 hours. If there is reappearance of signs of poisoning, injections of both sodium nitrite and sodium thiosulphate should be repeated but using each in one half of the dose used previously. The injections may be repeated for prophylactic purposes two hours after the first injections even if the patient is apparently well. If respiration has stopped but the pulse is beating, artificial respiration according to Schafer's manual method should be applied immediately to keep the heart beating. The handkerchief containing amyl nitrite should be laid over the patient's nose as it sometimes helps the respiratory movements to resume. As soon as signs of breathing appear, injection of the above mentioned solutions should be promptly made.

The prone pressure method of resuscitation (Schafer method) should be known to all fumigation operators and members of the staff of fumigation houses. If

necessary they should be given a special training. A full description of the method should also be prominently displayed in the fumigation houses. Oxygen—carbondioxide inhalation treatment is a valuable aid to drive the gas from the blood ; the apparatus for giving this treatment should therefore be close at hand always. It must however be borne in mind that the inhalator while being an aid to resuscitation cannot be a substitute for the Prone pressure method. The two may however be used simultaneously until the patient breathes without any assistance after which if necessary the inhalation only may be continued.

The Prone pressure method of resuscitation (Schafer system) is briefly as follows :

1. The patient should be laid on the stomach with head to the windward direction, one arm extended directly overhead, the other bent at the elbow. The face which is turned outwards should rest on the hand or forearm so that the nose and mouth are free for breathing.

2. The rescuer or person giving artificial respiration should kneel, straddling the patient's thighs, with his knees close to the hip bone.

3. The palms of the hands should be placed on the small of the back with the fingers resting on the ribs, the little finger just touching the lowest rib and with the thumb and fingers just out of sight.

4. The arms should be held straight and the body swung slowly forward so that its weight is gradually brought to bear on the patient. The shoulder should be directly over the heel of the hand at the end of the forward swing. The elbows should not be bent and the pressure should be maintained for approximately two seconds.

5. The body should be immediately swung back to remove the pressure completely.

6. The movements of compression and release should be repeated 12 to 15 times per minute.

7. This procedure should be carried on without interruption until breathing is restored, if necessary four hours or longer or until a doctor declares that life is extinct.

N. B.—In cases of gas asphyxiation, breathing has sometimes been reestablished even after eight hours of resuscitation. The doctor should therefore make a number of careful examination to determine absolute evidence for example, the onset of rigor mortis before the patient is declared dead and resuscitation is given up.

APPENDIX III

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Eriophyes quadrisetus F. Thomas (Juniper blister mite)	Eriophyidae	Acarina	*Juniperus communis* (Red cedar)	Europe	Easily introduced in nursery stock. Causes deformations in the fruit and needles
Eriophyes vitis Landois (Grape blister mite)	do.	do.	Grape (*Vitis* sp.)	Europe, Armenia, North America	Causes much damage to the vine. Imported into U. S. A. along with nursery stock
Paratetranychus citri Mc Gregor (Red spider mite)	Tetranychidae	do.	Citrus	U. S. A.	Does serious damage in arid coastal regions of California
Paratetranchus pilosus (Canastrini and Fanzago) (European red mite)	do.	do.	Most deciduous fruit trees ; most injurious to plum, prune, apple and pear	Europe, U. S. A.	This pest which is widely distributed over continental Europe, was found in U. S. A. in 1911 and has rapidly spread. It is most injurious to apple, plum, prune and pear
Phyllocoptes oleivorus (Ashmead) (Citrus rust mite)	Eriophyidae	do.	Citrus	China, Japan, U.S.A., Philippines, Straits Settlements	Reduces the value of half of the oranges and grape fruit in Florida
Rhizoglyphus (*Cocpophagus*) *echinopus* F. and R. (Potato root mite)	Tyroglyphidae	do.	Potato, parsnip, tulip, lilies	France, Italy Portugal, Palestine, Chile, Australia, California	Introduced into U. S. A. along with imported potatoes. Very destructive to roots and tubers
Tetranychus exsiccator (Zehntner) (Sugarcane red spider)	Tetranychidae	do.	Sugarcane	Java	Causes considerable damage by sucking juice from the plants which consequently wither away
Tetranychus sexmaculatus Riley (Red spider mite)	Tetranychidae	do.	Citrus	U. S. A.	Does serious damage in the Gulf States of U. S. A.

Adoxus obscurus Linnaeus		Coleoptera	*Epilobium angustifolium* (Fireweed and grape)	Algeria, France, Italy, Germany, U. S. A.	
Agrilus sinuatus (Olivier) (Sinuate pear borer)	Buprestidae	do.	Pear, hawthorn	Europe, U. S. A.	This is a European insect. Its first reocrd in U. S. A. was at New Jersey in 1894 where it appears to have been introduced
Agrilus occipitalis Eschsh. (Citrus bark borer)	do.	do.	Citrus	Philippines	A serious pest
Agrilus viridis Linnaeus (Flat headed wood borer)	do.	do.	Oak, beech, alder, aspen, linden, birch, rose, grape, maple, pine	Europe (Austria, Germany)	
Agriotes lineatus (L.)	Elateridae	do.	Tobacco, clover, hops, corn, potatoes, rutabagas	Practically all over Europe	Intercepted at quarantine in U. S. A. ports on potatoes and rutabagas
Agriotes pilosus Lacordaire (Tobacco wire worm)	do.	do.	Tobacco	Bessarabia, Portugal	
Anomola vitis Fabricius (Grape anomola)	Scarabaeidae	do.	Grape	Middle and Eastern Europe	
Anthonomus grandis Boheman (Cotton boll weevil)	Cureulionidae	do.	Cotton, *Hibiscus esculentus* and hollyhock	U. S. A., Mexico, Gautemala, Costa Rica, Cuba	This insect was first known only on wild cotton around Vera Cruz, Mexico. In 1880 it was found doing serious damage to cultivated cotton in the Moncolova District, Mexico. In 1892 it got introduced into U. S. A. It now causes 20 to 40 per cent loss of normal production. Loss estimated as \$100,000,000 to \$200,000,000 a year.

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Anthonomus grandis thurberiae Pierce (Thurberia weevil)	Curculionidae	Coleoptera	Cotton, wild cotton species, *Thurberia thespesioides*	U. S. A.	Found in the State of Arizona in U. S. A. The adjoining States have a quarantine against the pest
Anthonomus rectirostris (L)	do.	do.	Cherry and other fruits	France, Denmark Austria, Bulgaria, Czechoslovakia	Often intercepted during quarantine work at ports. Larva of this insect feeds on seed preventing fruit from ripening
Aphanistichus consanguineus Ritsema Bos (The flat-headed leaf-miner beetle)	Buprestidae	do.	Sugarcane	Java	
Apogonia destructor Ritsema Bos (Javan sugarcane beetle)	Scarabaeidae	do.	Sugarcane, grasses and various plants	Java	
Athous niger Linnaeus (Tobacco wire worm)	Elateridae	do.	Tobacco, beet	Europe	
Baris laticollis (Marsh)	Curculionidae	do.	Turnip	England, France, Portugal, Czechoslovakia and Poland	Intercepted at quarantine in the U. S. ports
Baris lepidii Germar	do.	do.	Horse radish	England, France, Portugal, Czechoslovakia and Poland	do.
Brachyrhinus sulcatus Fabricius (Grape root weevil)	Brachyrhinidae	do.	Grape	Europe, America, Australia	Introduced into Australia and America from its original home in Europe
Brontispa froggatti Sharp (The leaf hispa)	Hispidae	do.	Cocoanut palm	New Britain and Solomon Islands	

Byturus unicolor Say (Rasberry fruit worm)	Dermestidae	Coleoptera	Raspberry and Loganberry	U. S. A.	
Cerambyx cerdo Linnaeus (Great oak borer)	Cerambycidae	do.	Oak, ash, walnut	Europe, Sudan, Tunis	
Ceutorhynchus pleurostigma (Marsh.)	Curculionidae	do.	Turnip	England, Denmark, Scotland, Holland, Poland, Germany, France	Intercepted during plant quarantine work at U.S.A. ports very frequently
Chaetocnema confinis Crotch (Sweet potato flea beetle)	Chrysomelidae	do.	Corn, sweet potato	U. S. A.	
Chaetochnema pulicaria Melsheimer (Corn flea beetle)	do.	do.	Corn	U. S. A.	
Chrysobothris femorata (Olivier) (Flat headed apple borer)	Buprestidae	do.	All fruit and shade trees	U. S. A., Canada	
Chrysobothris mali Horn (Pacific flat-headed borer)	do.	do.	do.	do.	
Colaspis brunnea (Fabricius) (Grape colaspis)	Chrysomelidae	do.	Corn, grapes, strawberries, beans, clover, buckwheat, potatoes, cowpeas, apples, muskmelons	North America	
Conotrachelus aguacatae Barber	Curculionidae	do.	Avocado seeds	Mexico, Honduras, Costa Rica, Gautemala, Equador, British Honduras	Intercepted several times during plant quarantine work at ports in U. S. A.
Conotrachelus crataegi Walsh (Quince curculio)	do.	do.	Quince	U. S. A.	
Conotrachelus nenuphar (Herbst) (Plum curculio)	do.	do.	Plum, pear, peach, apple, apricot, cherry, prune, cherry, nectarine, etc.	U. S. A. and Canada	On account of the very destructive nature, Japan is conducting a strict quarantine against this pest [Kuwana, 1926]

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Cotinis nitida (Linnaeus) (Green june beetle)	Scarabaeidae	Coleoptera	Various fruit trees and plants in vegetable gardens	U. S. A.	
Curculio cerasorum Herbst (cherry weevil)	Curculionidae	do.	Cherry	Germany	
Cylas brunneus Fabricius (Liberian sweet potato weevil)	do.	do.	Sweet potato	Liberia	
Cylas femoralis Faust	do.	do.	do.	do.	Intercepted at quarantine in U. S. A. ports
Diabrotica duodecimpunctata Olivier (Spotted cucumber beetle)	Chrysomelidae	do.	Various cucurbits, string and Lima beans, peas, potato, beet, asparagus, egg plant, tomato, cabbage, corn	U. S. A. Canada, Mexico	
Diabrotica longicornis (Say) (Northern corn root worm)	do.	do.	Corn	U. S. A.	
Diabrotica soror Le Conte (Western spotted cucumber beetle)	Chrysomelidae	do.	Various cucurbits	U. S. A.	
Diabrotica trivittata (Mannerheim) (Western striped beetle)	do.	do.	Cucumbers muskmelons, pumpkins, squashes, watermelons	U. S. A.	
Diabrotica vittata (*Fabricius*) (Striped cucumber beetle)	do.	do.	Cucumbers, muskmelons pumpkins, gourds, squashes, watermelons, beans, peas, corn	U. S. A. Canada, Mexico	

Diaprepes abbreviatus Linnaeus (West Indies sugercane borer)	Brachyrhinidae	Coleoptera	Sugarcane, orange, guava, avocado, mango, rose, Indian corn, sweet potatoes, Bahama grass, limes and other plants	Porto, Rico, Barbados, West Indies	
Diphucephala colaspidoides Gyllenhal (The cherry green beetle)	Scarabaeidae	do.	Cherry	Southern Australia	
Desiantha nociva Lea (Tomato weevil)	Curculionidae	do.	Tomato, potato, and other vegetable plants	Australia	
Disonycha xanthomelaena Dalman (Spinach flea beetle)	Chrysomelidae	do.	Spinach	U. S. A.	
Epicaerus cognatus Sharp	Curculionidae	do.	Potato	Mexico	Intercepted at quarantine in the U. S. A. potatoes from Mexico
Entochira lateralis Boheman Syn. *Holaniara picescens* Fairmaire (The Bibit kever)	Tenebrionidae	do.	Sugarcane, tobacco	Java	See remarks under *Holaniara*
Epilachna varivestis Mulsant (Mexican bean beetle)	Coccinellidae	do.	Beans	U. S. A., Canada	This is a very injurious species. Japan is conducting a strict quarantine against it [Kuwana, 1926]
Epitrix cucumeris Harris (Potato flea beetle)	Chrysomeliadae	do.	Potato	U. S. A.	
Epitrix fuscula Crotch (Egg plant flea beetle)	do.	do.	Egg plant	U. S. A.	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Epitrix parvula (Fabricius) (Tobacco flea beetle)	Chrysomelidae	Coleoptera	Tobacco, potato, tomato, egg plant, chillies	U. S. A.	
Exosoma lusitanica (L.)	do.	do.	Cippolini, various bulbous plants and buds of grape	Morocco, Italy and France	Often intercepted on during quarantine inspection at U. S. A. ports
Euscepes batatae Waterhouse (West Indies sweet potato weevil)	Curculionidae	do.	Sweet potato	West Indies (Barbados, Antigua), Hawaii	This is often intercepted in quarantine work at California ports
Euscepes postfasciatus (Fairm.)	do.	do.		West Indies, Brazil and New Zealand	Intercepted at quarantine in U. S. A. ports
Fidia viticida Walsh (Grape root worm)	Chrysomelidae	do.	Grape and related wild plants	Eastern U. S. A.	Japan is conducting a strict quarantine against this insect [Kuwana, 1926]
Glyptoscelis squamulata Crotch		do.	Grape	California (U. S. A.)	A very serious pest in some parts of California
Haltica ampelophaga Leesb. (Vine flea-beetle)	Chrysomelidae	do.	Grape, willow	France, Italy, Spain, Algiers	
Haltica quercetorum Fondr. (Oak flea beetle)	do.	do.	Oak, Hazel, willow, birch, tea rse beach, alder	Europe (Russia, Germany)	
Heilipus lauri Boheman	Curculionidae	do.	Avocado seed	Mexico, Honduras, Gautemala, Costa Rica, Equador and British Honduras	Intercepted a number of times at U. S. A. ports

Hispa wakkeri Zehntner (Sugarcane hispid miner)	Curculionidae	Coleoptera	Sugarcane	Java	
Holoniara picescens Fairmaire (Bibit kever)	do.	do.	do.	do.	A living example of this beetle was once intercepted in India in a parcel of sugarcane setts received from Java [Fletcher, 1921]
Hylurgopinus rufipes Eich (Elm bark beetle)	Scolytidae	do.	Elm, basswood, ash	U. S. A Canada	
Hypera crinita Boheman (Potato leaf weevil)	Curculionidae	do.	Potato	Algeria, Tucis	
Hypera nigrirostris (Fabricius) (Clover bud weevil)	do.	do.	Red clover, alfalfa, sweet clover	Canada, U. S. A.	
Hypera punctata (Fabricius) (Clover leaf weevil)	do.	do.	Red clover, sweet clover, alfolfa	Southern Europe U. S. A., Canada	This insect is a native of S. Europe. It was not known in the U. S. A. until 1890, when it was first reported as injuring clover in New York. It has now spread all over U. S. A. and into Canada
Inesida leprosa Fabricius (Castilloa borer)	Cerambycidae	do.	Panama rubber (*Castilloa elastica*)	West and East Africa	
Lema cyanella Linnaeus (Grain leaf beetle)	Chrysomelidae	do.	Grasses, grains, especially oats	Serious in S. Europe	
Leptinotarsa decemlineata Say (Colorado beetle)	do.	do.	Potato, tomato, egg plant, tobacco, pepper, ground cherry, thorn apple, jimson weed henbane, horse nettle, belladona, petunia, cabbage, thistle, mullein	U. S. A., Canada, Spain, Austria, Switzerland, Italy, Belgium, France, Luxemburg, Germany, Lichtenstein	Original home of the insect in the U. S. A. is believed to have accompanied potatoes shipped to American Expeditionary Forces to Europe during World War I

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Leptops hopi Schonherr (Apple rot borer)	Curculionidae	Coleoptera	Apple, pear, cherry	Victoria (Australia)	
Macrodactylus subspinosus Fabricius (Rose chafer)	Scarabaeidae	do.	Grape	U. S. A., Canada	Japan is conducting a strict quarantine against this insect [Kuwana, 1926]
Melanauster chinensis Forst.	Cerambycidae	do.	Citrus, mulberry, apple, fig, casuarina	China, Japan, Korea	
Meligethes aeneus Fabricius	Nitidulidae	do.	Turnip, rape, cabbage and other crucifers	Europe	
Matamasius hemipterus Linnaeus (West Indies sugarcane borer)	Calandridae	do.	Sugarcane	West Indies, Trinidad	
Metamasius ritchiei Marshall	do.	do.	Pine apple	Jamaica, Mexico	Believed to have been introduced into Mexico from Jamaica
Metamasius sericeus Olivier (Sugarcane borer)	do.	do.	Sugarcane	Cuba, West Indies, Costa Rica, Barbados, the Canal Zone, Peru	Intercepted at U. S. A. ports a number of times during plant quarantine inspection
Naupactus leucoloma Boheman (White fringed beetle)	Curculionidae	do.	Peanuts, corn, sugarcane, cotton cowpeas, velvet beans, cabbages, sweet potatoes, lucerne	U. S. A., Australia	Has probably spread to Australia from the U.S.A.
Palacopus costicollis Marsh.	..	do.	Yams	Germany	Frequently intercepted at quarantine in the U. S. A. ports

Pantomorus godmani (Crotch) (Fuller's rose weevil)	..	Coleoptera	Citrus, avocado, walnut	California (U.S.A.)	
Pharaxonotha kirschi Reitt (Mexican grain beetle)	Cryptophagidae	do.	Corn, yams	Mexico, Guatemala, U. S. A., Brazil	Imported into U. S. A. from Mexico
Phyllotreta armoraciae (Koch) (Horse radish flea beetle)	Chrysomelidae	do.	Horse radish	U. S. A.	
Phyllotreta vittata Fabricius (Striped cabbage flea beetle)	do.	do.	Cabbage	do.	
Phytalus smithi Arrow (Brown hard back beetle)	Scarabaeidae	do.	Sugarcane	Mauritius, Barbados, Trinidad	Original home of the insect is Barbados. Introduced into Mauritius along with cane setts, it has been found to destroy entire fields
Phryneta spinator Fabr.	Cerambycidae	do.	Fig particularly. Also apple, apricot, peach, pear, plum	Africa	
Plocaederus ruficornis Newman (Mango bark borer)	do.	do.	Mango	Philippines	
Popillia japonica Newman (Japanese beetle)	Scarabaeidae	do.	Over 250 kinds of plants, deciduous fruit and shade trees, corn, soya beans, garden flowers, vegetables and various weeds	Japan, U. S. A.	This insect was imported into New Jersey (U. S.A.) from Japan on the roots of nursery stock about 1916
Premotrypes solani Pierce (Peruvian potato weevil)	Brachyrhynidae	do.	Potato	Peru and other parts of South America	Live specimens often obtained from South American potatoes in quarantine work at U.S.A. ports

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Promecotheca cumingii Baly (The cocoanut leaf miner beetle)	Hispidae	Coleoptera	Cocoanut	Philippines	
Pylloides attenuata Koch.	Chrysomelidae	do.	Hops, hemp	Europe (Russia, England)	
Rhabdocnemis obscurus Boisduval (Hawaiian sugarcane borer)	Calandridae	do.	Banana, sugarcane, cocoanut, sago-palm, royal palm, wine palm, papaya	Hawaii, Jamaica, Barbados, St. Kitts, Antigua, St. Lucia, British Guiana, Fiji, New Guinea, New Ireland, Tahiti, Queens land, Malaya archipelago	
Rhigopsidius tucumanus Heller (Argentine potato weevil)	Psaliduridae	do.	Potato	Argentine, Peru. Bolivia, Chile	Bores in potato making it unfit for use. Intercepted alive in U. S. A. from S. American potato
Rhizopertha collaris Erichson (Apple tree borer)	Bostrychidae	do.	Apple	Australia, Tasmania	
Rhynchophorus palmarum Linnaeus (Palm weevil)	Calandridae	do.	Palm, sugarcane	British Honduras, Trinidad, Lesser Antilles, Brazil	
Rhynchites cupreus Linnaeus	Rhynchitidae	do.	Plum, prune, cherry	Europe	
Saperda calcarata Say (Poplar borer)	Cerambycidae	do.	Poplar, cottonwood, aspen, willow	U. S. A., Canada	

Saperda candida Fabricius (Round headed apple borer)	Cerambycidae	Coleoptera	Apple, pear, quince	U. S. A., Canada	On account of the very destructive nature of this insect, Japan is conducting a very strict quarantine against it [Kuwana, 1926]
Scolytus multistriatus Marsham (European bark beetle)	Scolytidae	do.	Elms	do.	
Scolytus rugulosus Ratzeburg (Shot hole borer or fruit tree bark beetle)	do.	do.	Apple, peach, plum, cherry, quince	U. S. A., Europe	This insect is a native of Europe and is now generally distributed over U. S. A.
Sphenophorus sacchari	Curculionidae	do.	Sugarcane	Antigua, West Indies, Guiana	A parcel of sugarcane setts once received in India from Antigua was found to contain two living larvae and cocoons of this species. [Fletcher, 1921]
Sinoxylon perforans Schrk. (Grape-vine flat-headed borer)	Bostrychidae	do.	Grape, oak, elm, horsechestnut	Various countries of Europe	Bad on grape in Italy
Sinoxylon sexdentatum Olivier (Grape-vine flat-headed borer)	do.	do.	Grape, *quercus sessiflora*	Spain, France	
Stenoma catenifer Wlsm.	do.	do.	Avocado seed	Mexico, Costa Rica, Honduras, British Honduras, Equador, Guatemala	Often intercepted at U. S. A. ports during plant quarantine inspection
Tachypterellus consors Dietz.	Curculionidae	do.	Apple and other fruit trees	U. S. A.	
Tachypterellus consorscerasi List	do.	do.	do.	do.	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Tachypterellus quadrigibbus magnus List (Western or larger apple curculio)	Curculionidae	Coleoptera	Apple, quince, pear, cherry, haw, etc.	U. S. A.	
Trichobaris trinotata (Say) (Potato stalk borer)	do.	do.	Potato, egg plant	do.	In some sections of U. S. A. this insect becomes so abundant as to destroy entire fields. Japan is conducting a strict quarantine against the pest
Uracanthus acutus Blackburn	Cerambycidae	do.	Peach, apricot, plum	Australia	
Xyleborus coffeae Wurth (Coffee beetle)	Scolytidae	do.	Coffee	Dutch East Africa Java, Tonkin	
Trypopremnon latithorax Pierce	Brachyrhinidae	do.	Potato	Peru	Often intercepted alive in S. American potatoes at the U. S. ports
Xyleborus perforans Wallaston (Sugarcane ambrosia beetle)	Scolytidae	do.	Sugarcane	British Guiana Dutch Guiana, Trinidad, and other parts of northern S. America	This pest can easily be transported in shipments of seed cane
Trypopremnon sanfordi Pierce	Brachyrinidae	do.	Potato	S. America	Frequently intercepted in S. American potatoes at U. S. ports during plant quarantine inspections

Stephanoderes hampei Ferrari	Brachyrinidae	Coleoptera	Coffee	Java, Ceylon, Malay Peninsula, Dutch East Indies, West Indies, Uganda, Belgian Congo, French West Africa, Kenya, Tanganyika, French Togoland, Cameroons	A very injurious pest. A large number of countries have a quarantine against this insect
Anastrepha ludens Loew (Mexican fruit fly)	Positae	Diptera	Guava, grape fruit, apple, citrus, mango, plum, pe ach, pear, quince, sapota, apricot, mammea	Mexico, Central America, Texas, Guatemala	Introduced into Texas, U. S. A. from Mexico Very destructive. Large sums of money have been spent for eradicating it. Several countries have quarantines against the pest
Anastrepha acidusa Walk (West Indian fruit fly)	do.	do.	Guava, grape, apple, citrus, mango, plum, peach, rose apple	Virgin Islds., St. Kitts and Nevis, St. Lucia, Cuba, Dominican republic, Jamaica, Haiti, British West Indies, Key West	Often obtained in quarantine work at U.S.A. ports
Anastrepha grandis (Macq.)	do.	do.	Pumpkins	Brazil, Argentina	do.
Anastrepha serpentina Weideman	do.	do.	Various kinds of fruits	....	
Anthomyia radicum Meigen (Radish fly)	Anthomyidae	do.	*Raphanus* spp. (including radish)	Europe	
Cecidomyia humuli Theobald (Hop midge)	Itonididae	do.	Hops	England	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Ceratitis capitata Wiedeman (Mediterranean fruit fly)	Positae	Diptera	Citrus, peach, plum, apple, pomegranate, nectarines, pear, loquats, quinces, coffee berries, grape fruits, etc.	Tropical and sub-tropical regions, Bermuda, Brazil, Hawaii, Eritria, S. Africa, Spain, Portugal, Australia, Palestine, Egypt, Argentine, British East Africa, Algeria, Tunisia, Uganda, Dahomey, Nigeria, Congo, Rhodesia, Morocco, Tasmania, France, Albania, Greece, Italy, Sicily, Cyprus, Malta, Madevia, Canary Island, Madagascar, Cape verde	Doubtful record in India; believed to be from imported fruit. Not recorded again. Extremely destructive. U. S. A. has a stric- quarantine against it. Introduced into Florida. It cost $7,000,000 to eradicate
Chaetodacus tryoni Froggatt (Queensland fruit fly)	do.	do.	Citrus, apple, banana, apricot, custard apple, cherry, date, fig, grape, mango, plum. papaya, tomato, walnut	Queensland (Australia)	
Chortophila ciliicrura Rondani (Shallot fly)	Anthomyidae	do.	*Allium* sp. (including shallot), asparagus	Europe	
Clinodiplosis mosellana Gehin (Grain gall midge)	Itonididae	do.	Wheat, rye, barley	do.	

Contarinia pisi Winn (Pea midge)	Itonididate	Diptera	Pea	Europe	
Dasyneura pyri Bouche (Pear leaf curling midge)	Itonididae	Diptera	Pear	Europe	
Dacus raratongae Froggatt	Trypetidae	do	Mango	Raratonga and Cook Islands	
Dacus tongensis Froggatt .	do.	do.	do.	Tonga	
Dacus vertabratus Bezzi .	Positae	do.	Several fruits .	Africa, Egypt, Italy, Greece, Portugal, Spain, Sicily	
Epochra canadensis Loew. (The currant and Gooseberry fly)	do.	do.	Gooseberry and currant	North America	
Eumerus strigatus Fabricius (Lesser bulb fly)	Syrphidae	Diptera	Onions, iris	Europe, U.S.A. .	Introduced into U. S. A. from Europe. Introduction reported first by Felt from Iris roots at Saratoga springs, N. Y. (U. S. A.)
Hylemyia antiqua Meigen (Onion maggot)	Anthomyidae	do.	Onion	Europe, U. S. A. .	Introduced into U. S. A. from Europe
Hylemia coarctata Fallen (Wheat bulb fly)	do.	do.	Rye, wheat, barley	Middle and north of Europe	One specimen recorded Colorado, U. S. A.
Lonchaea splendida (Metallic tomato fly)	Trypetidae	do.	Tomato, potato, egg plant and other Solanaceae	New Zealand, Australia, Pacific Islands	
Merodon equestris Fabricius (Narcissus fly)	Syrphidae	do.	Onion, narcissus and daffodil bulbs	Europe, the U. S. A., Canada and New Zealand	This insect is of European origin. Introduced into U. S. A., Canada and New Zealand. It is often encountered in quarantine work in foreign shipments of bulbs in U. S. A. ports

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Oscinis frit Linnaeus (Frit flies)	Oscinidae	Diptera	Oats, barley, wheat, rye	Europe, America	Introduced into America from Europe
Phytomyza affinis Fallen (Marguerite fly)	Agromyzidae	do.	Tobacco, cosmos, celery, carrot, pea, helianthus, lettuce, dahlia etc.	Tasmania, New Zealand Australia, Europe, U. S. A.	Introduced into U. S. A.
Contarinia tritici Kirby (Grain gall midge)	Cecidomyiidae	do.	Wheat, barley, rye	Europe, U. S. A.	Introduced into U. S. A. Causes serious injury (Pierce)
Phytophaga destructor Say (Hessian fly)	do.	do.	Wheat, barley, rye	North America, Caucasus region of Russia	Introduced into U. S. A. It is believed to have been introduced in U. S. A. in straw bedding used by the Hessian troops during revolutionary war, as it was first noticed on Long Island in 1779. U. S. A. spends at least $100,000,000 a year against it.
Rhagoletis cingulata Loew (Cherry fruit fly)	Positae	do.	Cherry, pear, plum	U. S. A. and Canada	On account of the very destructive nature of this insect Japan is conducting a very stricted quarantine against it
Rhagoletis pomonella Walsh (Apple fruit or blue berry maggot fly)	do.	do.	Apple, blue berry, cherry	U. S. A. and Canada	A serious pest in U. S. A.
Trichocera hiemalis	Mycelophilidae	do.	Turnip, cabbage	England	

Trypeta musae Froggatt (Spotted fruit fly)	Positae	Diptera	Plum pear and other fruits		
Aleurodicus destructor MacKie (Cocoanut white fly)	Aleyrodidae	Hemiptera	Cocoanut palms	Philippines	
Aleurothrixus howardi (Quaintance)	do.	do.	Citrus	Florida (U. S. A.), West Indies, Cuba	
Aleurolobus olivinus Silvestri (Olive white fly)	do.	do.	Olive	Italy	
Anasa tristis De Geer (Squash bug)	Coreidae	do.	Cucurbits	U. S. A., Central America, Canada	
Blissus leucopterus (Say) (Chinch bug)	Lygaeidae	do.	Corn, wheat	U. S. A., Canada, Central America, Mexico	Very destructive ; Japan is conducting a very strict quarantine against this insect. [Kuwana, 1926]
Chionaspis furfura Fitch (Scurfy scale)	Coccidae	do.	Apple, pear gooseberry, currant other deciduous and bush fruit trees	U. S. A.	Japan is conducting a strict quarantine against the scurfy scale
Biprorulus bibar Bred	..	do.	Citrus	Australia	A serious pest
Eurythroneura comes (Say) (Grape leaf hopper)	Cicadelidae	do.	Grape, Virginia creeper, apple	U. S. A.	The most important pest of the grape
Hetrocordylus malinus Reuter (Apple red bug)	Miridae	do.	Apple, pear	U. S. A., South eastern Canada	
Lepidosaphes ficus (Signoret) (Mediterranean fig scale)	Coccidae	Hemiptera	Fig	Algeria, U. S. A.	Introduced into California in 1905 on fig cuttings from Algeria

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Murgantia histrionica (Hahn) (Harlequin bug)	Pentatomidae	Hemiptera	All Cruciferae, potato, egg plant, okra, bean, beet, fruit trees and various field crops	Mexico, U. S. A.	
Perkinsiella saccharicida Kirkaldy (Sugarcane leaf hopper)	Cicadellidae	do.	Sugarcane	Hawaii, Australia	
Phoenicococcus marlatti Cockerell	Coccidae	do.	*Phoenix dactylifera*, *P. canariensis*, *P. reclinata*	U. S. A., Egypt Algeria, Mediterranean coastal plain and the Sahara oases	Egypt is believed to be the native home of this insect
Phylloxera vitifoliae Fitch (Grape phylloxera)	Phylloxeridae	do.	Grape	North America, France, Australia, S. Africa	This pest was introduced into France from America about 1860. Within 25 years this insect had destroyed nearly one-third of the vine yards more than 2,500,000 acres
Pseudococcus capensis Brain (Cape Mealy bug)	Coccidae	do.	Grape, pumpkin, red clover and a host of other plants	South Africa	One of the worst pests of grape in the S. Africa
Psylla mali Schmid Apple psylla)	Psyllidae	do.	Apple	Europe	
Psylla pruni Scopoli Plum Psylla)	Psyllidae	do.	Plum	Europe, Siberia	

Psylla pyrisuga Förster (The large pear psylla)	Psyllidae	Hemiptera	Pear	Europe, Japan	Very injurious in Central Europe and Japan
Pulvinaria aurantii (Cockerell) (Orange pulvinaria)	Coccidae	do.	Citrus	Japan	Clausen lists this species as third most important on citrus
Scotinophora lurida	Pentatomidae	do.	Rice, sugarcane	Formosa, Japan	Is very destructive in certain localities of Japan
Phoeococoris sulciventris Stal (Bronze orange bug)	..	do.	Citrus	Australia	
Stenocranus saccharivora Westwood (West Indies cane fly)	..	Fulgoridae	Sugarcane	West Indies	
Stephanites pyri Fabricius (The pear tingis)	Tingitidae	do.	Pear, apple, persimmon	Europe	A serious pest of apple and pear in Europe. Intercepted a number of times in persimmon fruit arriving in baggage from Italy at U. S.A. ports
Tomaspis varia Fabricius (Sugarcane frog hopper)	Cercopidae	Hemiptera	Sugarcane, corn, grasses	Trinidad	A very serious pest
Unaspis citri (Comstock) (White scale of orange)	Coccidae	do.	*Citrus* sp.	Recorded in several parts of the world	Introduced into some parts of U. S. A. along with nursery stock probably from the orient
Unaspis yanonensis (Kuwana)	do.	do.	do.	Japan, China	Very destructive. Frequently intercepted at quarantine in U. S. A. ports. The native home of this insect is believed to be China

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Cephus cinctus Norton (Wheat stem saw fly)	Cephidae	Hymenoptera	Rye, wheat, barley	North America	Very destructive in the U. S. A.
Cephus pygmaeus Linnaeus (European wheat saw fly)	do.	do.	Wheat, rye, timothy and other cereals and grasses	Europe, U. S. A.	This insect can be easily imported in straw. Introduced into U. S. A. found in New York and Pennsylvania States
Harmolita grandis (Riley) (Wheat straw worm)	Chalcididae	do.	Wheat	U. S. A.	Very destructive. Japan has a strict quarantine against the pest [Kuwana, 1926]
Harmolita tritici (Fitch) (Wheat joint worm)	do.	do.	do.	U. S. A.	do.
Janus compressus Fabricius (Bud stinger)	Tenthredinidae	do.	Pear	Europe	
Pamphilius flaviventris Retz.	do.	do.	Pear, plum, cherry	Europe	
Pteronidia ribesii (Scopoli) (Imported currant worm)	do.	do.	Currant, gooseberry	Europe, Canada U. S. A.	Imported into America from Europe about 1857
Termes australis Hagen (Victorian white ant)	Termitidae	Isoptera	Apple	Australia	
Alsophila pometaria (Harris) (Fall canker worm)	Geomatridae	Lepidoptera	Apple	U. S. A. and Canada	Japan is conducting a strict quarantine against this pest [Kuwana, 1926]
Anarsia lineatella Zeller (Peach twig borer)	Gelechiidae	do.	Peach, plum, apricot and almond	U. S. A.	

Antographa brassicae Riley (Cabbage looper)	Noctuidae	Lepidoptera	All plants of the cabbage family, potato and tomato	U. S. A., Canada and Mexico	
Argyroplace leucotreta Meyrick (False codling moth)	do.	do.	Plum, citrus, guava pomegranate, peach persimmo, olive, walnut	South Africa	
Argyresthia conjugella Zeller (Apple moth)	Hyponomeutidae	do.	Apple, cherry and plum	Europe, U. S. A., British Columbia, and Japan	Introduced into U. S. A. along with nursery stock
Argyresthia vitidella Fabricius (Cherry fruit moth)	do.	do.	Cherry, hawthorn	England	
Argyrotaenia citrana (Fern) (Orange tortrix)	do.	do.	Citrus	California (U. S. A.)	
Blastodacna vinolentella H. S. (Pith moth)	Elachistidae	do.	Apple	England and Europe	
Boarmia gemmaria Brahm	Geometridae	do.	Grapes, rose, wild honey suckle	Europe	
Critripestis sagittiferella Moore		do.	Citrus	Malaya, Dutch East Indies	There is sometimes 100 per cent loss of grape fruit due to this
Clysia ambiguella Hübner (The Cochylis)	Tortricidae	do.	Grape	Europe	
Cnethocampa processiona Linnaeus (Oak procession moth)	Cnethocampidae	do.	Oak	do.	
Caleophora lutipenella Zell. (Oak bud moth)	Elachistidae	do.	Oak, birch	Germany	
Conogethes punctiferalis Guerin	Pyralidae	do.	Peach	Australia	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Conopia exitiosa (*Say*) (Peach borer)	Aegeriidae	Lepioptera	Peach, wild and cultivated cherry, plum, prune, nectarine, appricot and ornamental shrubs of the genus prunus	U. S. A. and Canada	On account of its very destructive nature, Japan is conducting a very strict quarantine against it [Kuwana, 1926]
Cryptophaga unipunctata Donovan	Xyloryctidae	do.	Cherry, peach, honey suckle	Australia	
Cydia saltitans (Westwood) (Mexican jumping bean moth)		do.	Mexican Jumping beans	Mexico and U. S. A.	Encountered a number of times in quarantine work in Hawaii
Diatrea canella Hampson	Pyralidae	do.	Sugarcane and grasses	Trinidad, Grenada, Guiana	
Diatraea crambidoides Grote (Southern corn stalk borer)	do.	do.	Corn, sorghum, Johnson grass	U. S. A., Mexico South America	One of the most destructive corn insects in the South U. S. A. Often responsible for reduction in yields of 15 to 50 per cent
Diatraea lineolata Walker	do.	do.	Sugarcane, grasses	Trinidad, West, Indies, Central and South America	
Diatraea saccharalis Fabricius	do	do.	do.	Mexico, West Indies, United States	
Diatraea striatalis Snellenhoeven	do	do.	do.	West Indies, Formosa and Java	

Ephestia elutella (Hübner) Tobacco moth	Pyralidae	Lepioptera	Cured tobacco, nuts, chocolate, and many other dried vegetable products	Practically cosmopolitan	Very bad in the U. S. A., on tobacco. Not recorded so far in India
Ereunetis flavistriata Walsingham (Sugarcane bud moth)	Tineidae	do.	Sugarcane, palms, banana and pineapple	Hawaii	
Epinota opposita Heinrich	..	do.	Beans, chillies, alfalfa, cowpeas	Peru and Mexico	Intercepted at quarantine in the U. S. ports
Hepialus humuli Linnaeus (Hop root borer)	Hepialidae	do.	Hops, potato, rape, corn, sorrel, dandelion	Europe	
Hyphantria cunea (Drury) (Fall web worm)	Arctiidae	do.	Apple	U. S. A. and Canada	Japan is conducting a strict quarantine against the pest [Kuwana, 1926]
Laspeyresia dorsana Fabricius (Pea moth)	Tortricidae	do.	Peas	Europe	
Ephestia kuehniella Zeller (Mediterranean flour moth)	Pyralidae	do.	Mostly found in flour, it will also attack whole grain of wheat bran, breakfast foods, corn and other grains and pollen in beehives	Europe, U. S. A., Canada and several other parts of the world	This insect is of European origin. Not recorded so far in India. Recorded in Canada for the first time in 1889, it has spread throughout Canada and U. S. A.
Laspeyresia nigricana Stephens	Tortricidae	Lepidoptera	Peas	Europe, Canada and U. S. A.	This insect is of European origin and has been in America since about 1900
Laspeyresia molesta (Busck) (Oriental fruit moth)	do.	do.	Apple, pear, peach, quince, plum	U. S. A., Canada, Japan, Korea, China, France, Italy, Australia	This insect is an oriental species not so far recorded in India. It was introduced into U. S. A., along with imported nursery stock

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Ochsenheimeria taurella Schiffermüller (Rye stem borer)	Tineidae	Lepidoptera	Rye, grasses	Europe	Very injurious to winter rye; may attack other grain crops
Omiodes accepta Butler (Hawaiian sugarcane leaf roller)	Pyralidae	do.	Sugarcane and grasses, sedges	Hawaii and Peru	Does serious damage sometimes. Is liable to importation in seed cane
Paleacrita vernata Peck (Spring canker worm)	Geometridae	do.	Shaded fruit trees, apple	U. S. A. and Canada	Japan is conducting a strict quarantine against this pest [Kuwana, 1926]
Papilio cresphontes Cramer	..	do.	Citrus	U. S. A.	A serious pest in Florida
Porthetria dispar (Linnaeus) (Gypsy moth)	Lymantriidae	do.	Conifers and other decoration plants	Europe, United States and Canada	A native of Europe. This insect was brought into U. S. A. in 1869. It has cost the Massachussetts State more than a million dollar a year for the last 20 years
Polychrosis botrana (Schiffermüller) (The pyralid of the vine)	Olethreutidae	do.	Grape	Germany, Austria, Hungary, Switzerland, France, Italy, Asia Minor	Very injurious. This insect has been often obtained in quarantine work at U. S. A. ports. Imported grapes have been found infested with larvae of the species
Laspeyresia schistaceana Snellenhoeven (Gray borer of sugarcane)	Tortricidae	do.	Sugarcane	Java	A very bad pest. Is liable to importation in seed cane
Leucinodes elegentalis Geunee	Pyralidae	do.	Tomatoes	Mexico, Brazil	Intercepted at the quarantine in U. S. ports

Leucoptera coffeella Stainton (Coffee leaf miner)	Lyonetiidae	Lepidoptera	Coffee	Parto Rico, Brazil Cuba	A serious enemy reported as causing 20 to 30 per cent loss
Lemuana iridescens Bethune-Barer (Coconut leaf moth)	Zygaenidae	do.	Coconut palm, royal palm (*Oreodoxa regia*)	Fiji	Very injurious to foliage
Liparia (*Lymantria*) *monacha* Linnaeus (Nun moth)	Lymantriidae	do.	Deciduous ornamental and forest trees	Europe and U. S. A.	This is a European species. Specimens were first collected in U. S. A. at Brooklyn N. Y. in 1902
Melittia satyriniformis Hübner (Squash borer)	Aegeriidae	do.	Cucurbits	U S. A Canada and South America	A very pernicious borer
Nygmia phaeorrhoea (Donovan) (Brown tail moth)	Lymantriidae	do.	Deciduous shade and fruit trees	Europe, Nova Sootia, New Brunswick and U. S. A.	A native of Europe. This insect was introduced in E. Massachusetts (U. S. A.) on imported nursery stock about 1897. Japan is conducting a strict quarantine against it [Kuwana, 1926]
Polychrosis viteana (Clemens)	Olethreutidae	do.	Grapes	U. S. A. and Canada	
Prays oleellus Fabricius (Olive moth)	Hyponomeutidae	do.	Olives	France, Italy, Spain	A very serious pest
Protoparce quinquemaculata Haworth. (Tobacco horn worm)	Sphingidae	do.	Tobacco, tomato, brinjal, potato, chillies	U. S. A.	
Protoparce sexta (Johanssen) (Tobacco horn moth)	do.	do.	Tobacco, tomato, potato, chillies and brinjal	U. S. A.	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Pyrausta nubilalis Hübner (European corn borer)	Pyralidae	Lepidoptera	Millet, corn, potatoes, beans, beats	Europe, Canada, U. S. A., Guam, Japan, China	One of the most destructive pests of corn. Believed to have been introduced into N. America about 1908 or 1909 in shipments of broom corn from Italy or Hungary
Sesamia cretica Led. (Durra stem borer)	Noctuidae	do.	Sugarcane, corn, durra	Khartoum, Sudan	A very serious pest in Khartoum. Is liable to importation in seed cane
Sciopteron regale But. Grapegum worm	Sesiidae	do.	Grape	Japan	
Synanthedon tipuliformis (Linne) (Currant borer)	Aegeriidae	do.	Gooseberry, currant	North America	
Synanthedon tictipes (Grote and Robinson) (Lesser peach borer)	Aegeriidae	do.	Peach, plum, cherry, wild plum, wild cherry	U. S. A.	
Tinea granella Linnaeus (The wheat moth)	Tineidae	do.	Wheat, barley	Victoria, Australia, Europe, North America	Introduced into U. S. A. Causes serious injury to the seed heads
Tortrix ashworthani Newman (Light brown apple moth)	Tortricidae	do.	Apple	Australia	
Zeuzera pyrina Linnaeus (Horse chestnut borer)	Cossidae	do.	Elm, alder, ash, beach, birch, horse chestnut, linden, maple, oak, willow. poplar, buck thorn, spindle trees, mountain ash	Europe, North Africa	

Epacromia tamulus Fabricius	Acridiidae	Orthoptera	Sugarcane	Java	
Oxya intricata Stal	do.	do.	do.	Formosa, Java	
Scirtothrips citri (Moulton)	Thripidae	Thysanoptera	Citrus	California	Causes very great injury in drier regions of California and may do similar damage if introduced into India
Taeniothrips inconsequens Uzel (Pear thrips)	do.	do.	Apple, pear, appricot, cherry, grape, peach, and various other deciduous fruit trees	U. S. A. and Canada	On account of its very destructive habits, Japan is conducting a very strict quarantine against this pest

THE STRUCTURE OF XYLEM VESSELS IN THE NODAL REGION OF SUGARCANE IN RELATION TO ITS RESISTANCE TO RED-ROT (*COLLETOTRICHUM FALCATUM*, WENT)

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(With two test-figures)

Recent investigations in the red-rot resistance of cane at Louisiana have indicated a close relationship between the structure of fibro-vascular bundles and disease incidence in cane varieties. It has been considered that the rapid spread of red-rot disease from one part of cane to another is partly due to the migration of spores through the vascular bundles. Efforts at this station were made to elucidate the structure of vascular bundles at the nodes of certain sugarcane varieties in order to establish a relationship, if any, between their nodal anatomy and the resistance they offer to the spread of infection from one internode to another.

Markedly resistant and likewise susceptible varieties of sugarcane were selected ; Co.453, Co.393 and *desi dhor* representing the former group and Co.312 and Co.213 the latter. *Saccharum spontaneum* which is known for its very high resistance to the disease according to Butler and Khan [1913] was also included. Soon after the plants were received from the field, their top portions consisting of a few internodes with foliage were cut under water so that transpiration current was not broken. The cut ends of these tops were then immersed in a fairly concentrated Indian ink suspension in distilled water where they were allowed to remain for 48 hours. After taking them out of the suspension only the last two internodes, with one node in between, were retained and all subsequent observations were confined to the internode just above the one cut. From this, transverse sections were cut within half an inch of the node and were examined under the dissecting microscope.

Total number of vascular bundles, as also those showing the ascent of ink were counted per unit area to find out the percentage of the latter. Ten counts were taken in each section, five being from the periphery touching the epidermis and the rest from the central region. Eight different clumps of each variety were tested separately. The percentages of ink-showing vascular bundles of the different varieties under study are presented along with the averages of their linear-infections of the last five years obtained from the Mycology Section of this Station in Table I.

In Co.393 and *Saccharum spontaneum* the nodal regions below the internodes studied were macerated with boiling caustic potash solution. The parenchyma was dissolved leaving a tangled mass of vascular strands which were separated and stretched on slides with a view to trace the path of ink-particles through term.

In another set of experiments tops of Co.213 and Co.393 were cut under water and placed in suspension of red-rot spores in distilled water with a little cotton-blue. In this case also cross sections of internodes were studied exactly in the same way as before, to find out if spores could travel through the vessels across the nodes.

TABLE I

Average percentages of ink-showing vascular bundles in the plants studied and their relative linear-infections

Varieties	Ink-showing vascular bundles per cent of total bundles	Linear-infections in cm. (average of 5 years)	Remarks
S. spontaneum	*nil*	Highly resistant	Canes having linear infections less than 30 cm. are considered to be resistant.
Co.453	2·7	22·5	
Desi dhor	2·7	11·7	
Co.393	6·7	18·7	
Co.312	20·9	94·3	
Co.213	22·8	116·6	

It will be observed from the Table I that there is a close parallelism between percentages of ink-showing vascular bundles and the linear-infections. It is seen that in Co.453, *desi dhor* and Co.393 there are very few vascular bundles showing the presence of ink and, also that lesion-lengths do not go beyond 22·5 cm. Co.312 and Co.213 with their lesion-lengths of 94·3 cm. and 116·6 cm. respectively, also have, in turn, by far the maxima for the ink-conducting vascular bundles, viz., 20·9 per cent and 22·8 per cent. It is also very significant to note that in *Saccharum spontaneum* ink particles have not crossed the node even through a single vascular bundle. Thus the marked concurrence observed between the figures for ink-showing vascular bundles and varietal linear-infections possibly opens an avenue for such vascular counts and mycologist's findings to go hand in hand.

Now from Table I it can be deduced that while ink particles can travel across the nodes through a large number of vascular bundles in susceptible varieties, frequency of such bundles is much less in resistant ones. Its possible explanation seems to lie in the characteristics of vascular strands of the resistant cane varieties. It will be seen in Fig. 1 that in one metaxylem ink particle stops abruptly at one place. This can be attributed to the metaxylem being made up of a series of elongated cells placed end to end to form a sort of pipe-line as expressed by Eames and MacDaniels [1925]. The ends of these cells can easily be marked out by constrictions found along the length of the ink-column in the vessel. These constrictions indicate the location of septa which usually dissolve away except, perhaps, at the

FIG. 1. Metaxylem strands from the nodal region of Co. 393 showing the ascent of Indian ink (by camera lucida X22·75)

nodal regions. The ink-suspension has abruptly stopped in the vessel at one of these constrictions where a septum is intact which effectively blocks the passage of this duct. In the same figure ink particles appear to have punctured the septum of the other xylem vessel, and are able to escape through it. It, therefore, indicates that a weak septum can be ruptured by a strong current of suspended particles. It naturally implies that in *Saccharum spontaneum* vascular strands have got rather tough septa which serve as effective barriers for the onward flow of the ink particles. Thus, it could be stated that a sugarcane variety would owe its red-rot resistance to the presence of strong septa in its vessels at the nodes, while susceptible ones would have either weak septa or no septa at all in this region. Again, it would be clear from Table I that a small percentage of ink-showing vascular bundles does occur even in the resistant varieties, and also that small linear-infections do appear in them. It only means that no sugarcane variety is fully resistant to the disease, but that a so-called resistant type is only comparatively less susceptible.

While explaining the probable cause of variation in resistance to red-rot in sugarcane, Edgerton and Carvajal [1943] point out that spores of the fungus are able to migrate very rapidly in the ducts of fibro-vascular bundles of certain varieties and with difficulty in others. This was due to the fact that most of the ducts of the latter varieties are not open in the nodes. Our studies from spore suspension experiment also revealed the presence of spores in the xylem vessels in the post nodal region of the stem of Co.213 (Fig. 2), and not in Co.393. This, perhaps, could be due to the ease with which spores could travel along the 'open' vascular bundles of Co.213. It is also significant that spores were not seen in the intercellular spaces indicating that these do not serve as passage for the migration of spores from one region to the other.

FIG. 2. Cross section from post-nodal region of the stem of Co. 213 showing a spore in the meta-xylem (by camera lucida X106)

Indian ink particles, although very small (2 to 2·5μ) can be comparable to spores of the fungus (20μ long and 5μ broad) in as much as both of them are capable of being carried along with the transpiration current in the xylem vessels. The diameter of the xylem vessels has been found to be several times the length of the

spores. Therefore, these spores can move upwards like ink-particles within the vessels without difficulty and can pass through the nodes if the passage is ' open '.

In resistant varieties if red-rot infection starts, it generally remains confined to one or two internodes. In susceptible varieties, on the other hand, the infection spreads with ease from one internode to the other involving ultimately almost the whole length of the cane. If xylem vessels act as channels for rapidly conducting red-rot infection, as they appear to do, it can easily be assumed that varieties with ' closed ' vessels, i.e., with vessels having septa at the nodes, prevent the infection from spreading further. It, therefore, follows that a laboratory test with Indian ink suspension, as carried out in this investigation, would provide a quick method for determining the degree of red-rot resistance in sugarcane-varieties.

Summary.

Recent investigations suggest that rapid spread of red-rot in sugarcane is partly due to the migration of spores through the ' open ' vascular bundles at the nodes.

The immersion of cane tops in Indian ink suspension has shown that Indian ink particles are carried across the nodes through a larger number of vascular bundles in susceptible varieties as Co.312 and Co.213 than in the resistant varieties as Co.393, Co.453 and *desi dhor*. Examination of macerated vascular strand of the nodal region of Co.393 showed the presence of septa stopping the flow of ink through them.

The presence of red-rot spores has been found in xylem vessels of cane tops of Co.213 after immersion in a suspension of spores for 48 hours. This indicates that spores, like Indian ink particles, are carried through the xylem vessels and would be stopped by septa, if present.

These investigations suggest a quick laboratory test for assessing the degree of red-rot resistance in sugarcane varieties.

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REFERENCES

Butler, E. J , and Hafiz Khan, A. (1913). Red-rot of Sugarcane. *India Dept. agric. Mem., Bot. Ser.* 6 (5)

Eames, A. J., and Mac Daniels, L. H. (1925). *An introduction to Plant Anatomy;* 50-81

Edgerton, C. W., and Carvajal, F. (1943). Recent investigations on the red-rot of sugarcane. *Sugar Bull.* 22 (4), 26-29

CYTOGENETIC STUDIES ON CROSSES OF *GOSSYPIUM ANOMALUM* WITH CULTIVATED COTTONS I

[(*G. HIRSUTUM* × *G. ANOMALUM*) DOUBLED × *G. HIRSUTUM*]

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(Received for publication on 5 July 1948)

(With Plates VII, VIII and IX)

A NUMBER of interspecific hybrids and polyploids of *Gossypium* have been built up at the Agricultural Research Station, Surat, with *G. anomalum*, a wild African diploid species, as one of the parents. These are characterized by their vigorous and rapid growth, profuse scaffolding of branches, general healthiness and tolerance to some of the diseases and pests common to cultivated cottons. *G. anomalum*, by itself, is resistant to red mites, leaf roller, bud worm, semilooper and other leaf eating caterpillars [Margabandhu, 1941] and is almost immune from black-arm or angular leaf-spot disease caused by *Bacterium malvacearum* [Anson *et al* 1945]. The leaves of *G. anomalum* bear profuse growth of epidermal hairs on their laminae and veins—a character which is known to contribute to jassid resistance. In the case of fertile derivatives from *G. anomalum* crosses, having normal seed setting, the fibre shows some exceptional good qualities as regards length, fineness, strength, lustre and smooth silky feel. In spite of all these good qualities, however, the synthetic types have some undesirable features such as complete or partial sterility, small boll-size and brownish meagre lint closely matted round the seedcoat, which renders ginning operation difficult. Though on these grounds these types as such are not likely to be of immediate economic use, they are nevertheless useful for further hybridization work. Attempts are, therefore, being made at Surat, for the past several seasons, to transfer some of the useful characters of *G. anomalum* specified above, to cultivated cottons, through a series of appropriate crosses.

The present paper summarises the cytological studies on the first backcross generation of [(*G. hirsutum* × *G. anomalum*) Doubled × *G hirsutum*] and discusses the possible results in the light of its meiotic chromosome behaviour. The object of these crosses was to incorporate certain desirable traits of *G. anomalum* into the genotypic background of the cultivated tetraploid cottons. Beasley and Richmond [1943] have reported similar attempts to transfer *anomalum* characters to upland cottons.

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N

MATERIAL AND METHODS

Co2, an improved strain of acclimatised *G. hirsutum* (2n=52) [AA DD] cotton from Coimbatore, South India, was crossed with *G. anomalum* (2n=26) [BB] and the chromosomes in the sterile allo-triploid (2n=39) [ADB] thus obtained, were doubled by means of colchicine giving a fertile hexaploid (2n=78) [AA DD BB] [Amin, 1941, Iyengar, 1944, Patel *et al.*, 1946]. This hexaploid [(*G. hirsutum* × *G. anomalum*) F1 Doubled] [AA DD BB] was backcrossed to *G. hirsutum* (Co2) [AA DD] using the former as seed parent and as a result, 49 seeds were secured. Out of these, only 19 germinated and developed into mature plants, which formed the first backcross population. In view of their origin from the allo-hexaploid and allo-tetraploid parents denoted above, which involved the fusion of (ADB) female gametes with (AD) male gametes, these first backcross individuals were expected to be allo-pentaploids with [AA DD B] as their genomic constitution.

The seedlings were raised as pot-cultures during their earlier period of growth in the glass house and after collection of root tips, were transplanted in the field. Flower buds were collected during December to February 1946-47 between 11 to 12 a.m. on bright sunny days. They were fixed in Carnoy for two to four hours, treated in a mixture of concentrated HCl and 95 per cent alcohol in equal proportion for five minutes at 45°C., repeatedly rinsed in 95 per cent alcohol and temporarily stored in alcohol of the same strength. Anthers at the proper stages were smeared in acetocarmine containing a trace of ferric chloride. Slides were sealed with paraffin and these temporary mounts were used for microscopic examination. The root tip material did not give sufficient number of clear chromosome plates for somatic counts. Since the aceto-carmine preparations of P.M.C. were very clear, these were used both for determining the chromosome number (2n) and for their meiotic behaviour.

All chromosome drawings (Plate VII, figs. 1-5; Plate VIII, figs. 6-8; Plate IX, figs. 9-10) were made at bench level with the aid of a *camera lucida* using 1·8 achromatic oil immersion objective (95 ×) and compensating ocular (15 ×). In the case of other drawings (Plate IX, figs. 11-18) the same ocular was used in combination with a low power objective (10 ×).

OBSERVATIONS

The backcross population was more or less uniform except for a few morphological differences on the basis of which all the plants could be broadly classified into the following two groups :

(*a*) Plants with long, loose scaffolding, with dark green, broad, convex, hairy leaves having 3 to 5 well separated lobes. Pot-cultures 12/2, 3, 10, 17, 25, 26, 28, 30, 39 and 45 belonged to this class.

(*b*) Plants with short, compact scaffolding with light yellowish green, medium or small, concave, intensely hairy leaves having 3 to 5 lobes with overlapping margins. Pot-cultures 12/6, 9, 14, 23, 27, 35, 40 and 42 belonged to this class. The relative proportion of plants belonging to the above two classes was 10 : 9 or 1 : 1.

An examination of 18 plants for chromosome conjugation at the first metaphase during meiosis gave the following mean values (Table I).

EXPLANATION OF PLATE VII

Fig. 1. Diakinesis ; 11 I+27 II (2n=65)

Fig. 2. M-phase I ; 13 I +19 II +2 III+2 IV (2n=65)

Fig. 3. M-phase I ; 11 I ± 18 II + 3 IV+1 VI (2n=65)

Fig. 4. M-phase I ; 11 I+9 II+1 III+7 IV+1 VI (2n=66)

Fig. 5. M-phase I ; 7 I+19 II+4 IV+ 1 VI (2n=67)

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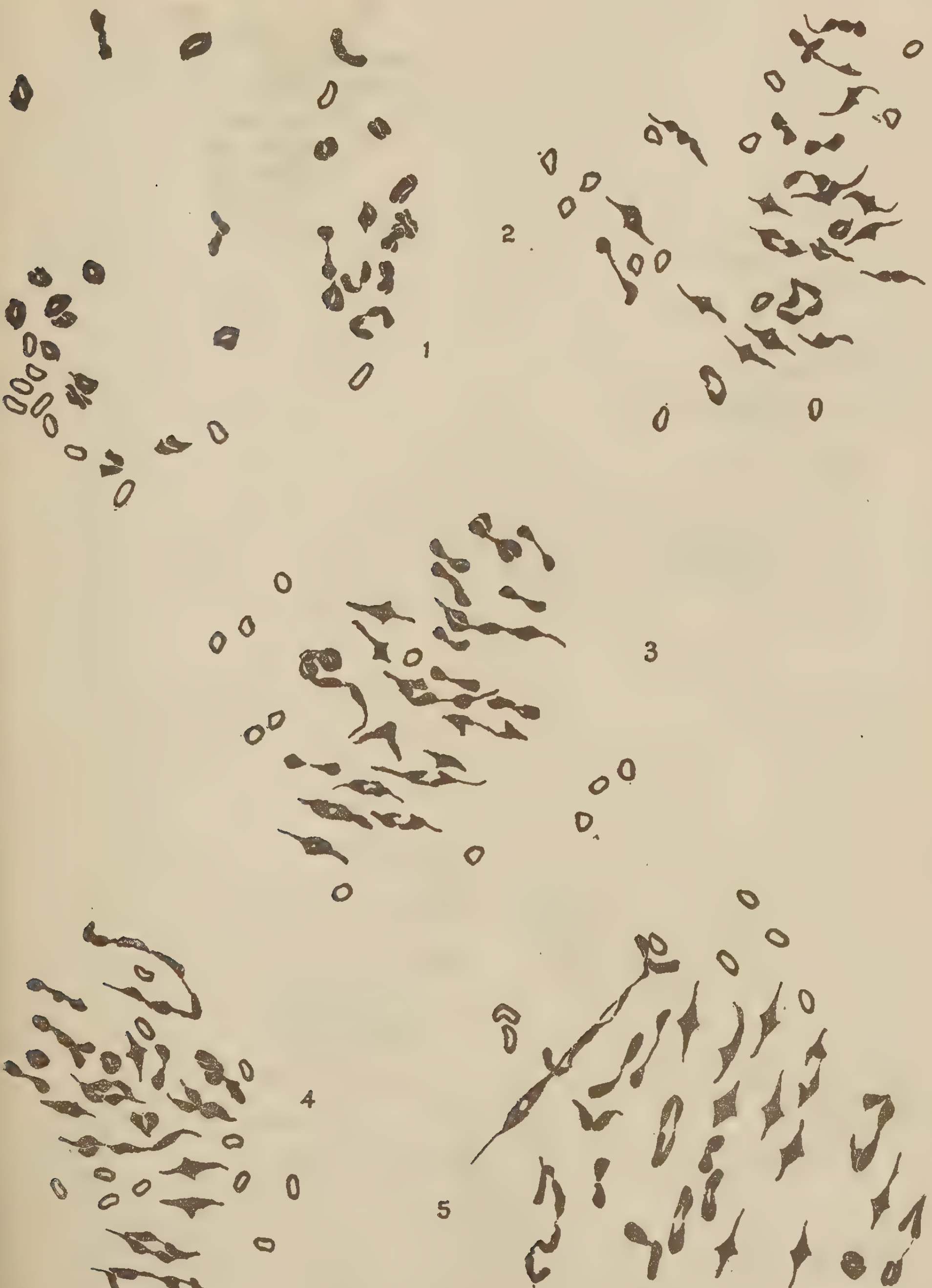
CYTOGENESIS IN [(*G. HIRSUTUM* × *G. ANOMALUM*) DOUBLED×*G. HIRSUTUM*]



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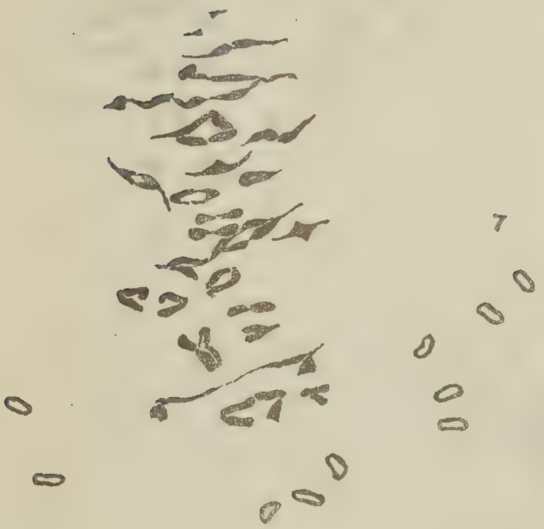

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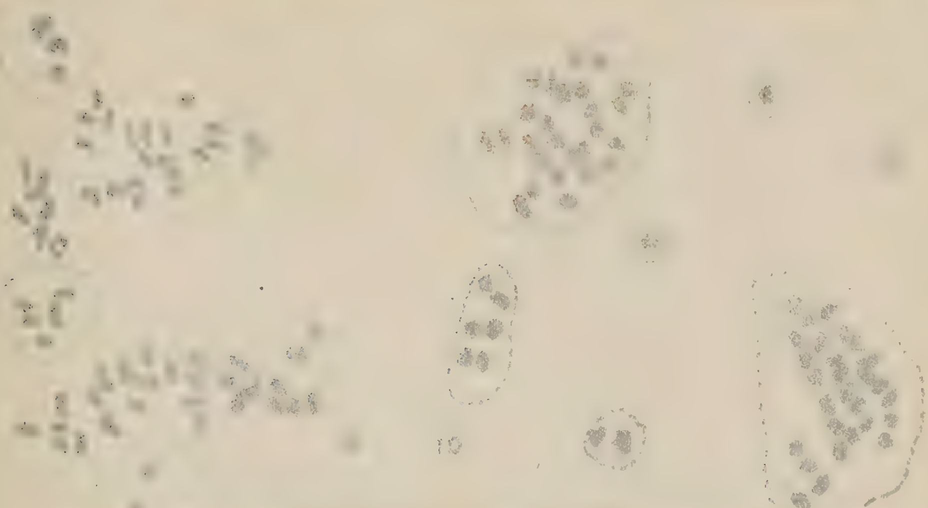
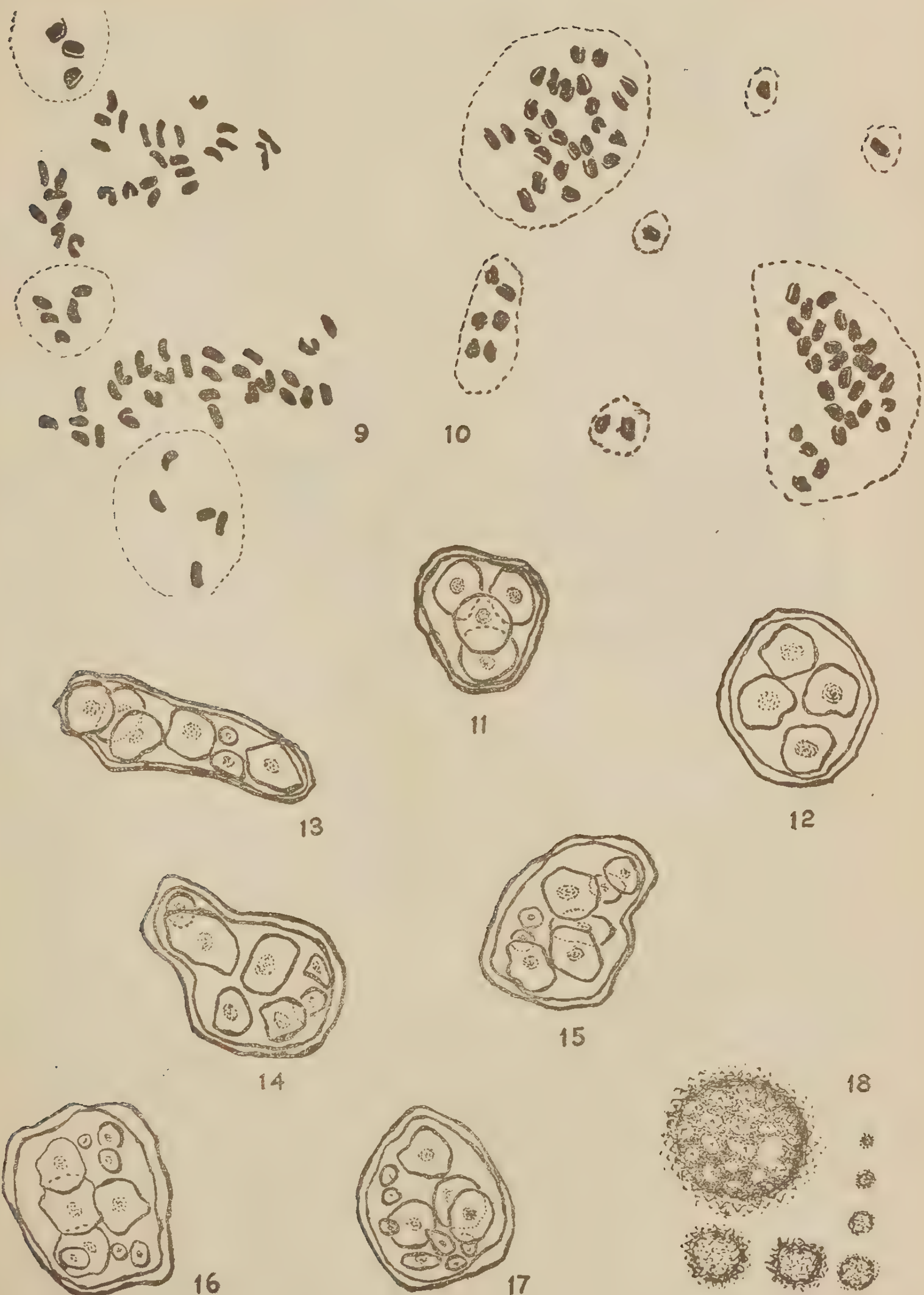


EXPLANATION OF PLATE VIII

Fig. 6. M-phase I ; 8 I+21 II+1 III+ 2 IV+1 VI (2n=67) Hexavalents in Figs. 5 and 6 showing precocious anaphasic separation forming a chromatin bridge.

Fig. 7. M-phase I ; 10 I+15 II+4 IV+2 VI+2 fragments (2n=68) Quadrivalent showing precocious anaphasic chromatin bridge.

Fig. 8. M-phase I ; 11 I +15 II+ 2 III+4 IV+1 VI (2n×69)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EXPLANATION OF PLATE IX

FIG. 9. Telophase I ; Showing 2 major and 3 minor groups containing 28, 27, 5, 5 and 3 chromosomes each ($2n=68$). Precocious deposition of cell wall around the three minor groups. The minor group containing 3 univalents showing longitudinal split

FIG. 10. M-phase II ; Showing 2 major and 5 minor groups containing 28, 26, 6, 2, 1, 1, 1 chromosomes each ($2n=65$). Cell wall being deposited around each group

FIGS. 11 to 12 showing P. M. C. with normal tetrad stage

FIGS. 13 to 17 showing P. M. C. with abnormal tetrad stages containing 7 to 11 microspores+micronuclei

FIG. 18 showing pollen grains, big and small with intergrades

TABLE I

Chromosome conjugation in the first backcross individuals [(G. hirsutum G. anomalum) F_1. *Doubled* G. hirsutum]

Serial number	Pot-culture number	Number of P.M.C. at m-phase studied	Mean chromosome conjugation					
			Univalents	Bivalents	Trivalents	Quadrivalents	Hexavalents	Mean chromosome number (2n)
1	12/6	4	15·25	17·50	..	2·25	1·00	65
2	12/35	3	10·00	19·67	..	3·00	0·67	65
3	12/40	6	10·00	19·34	0·17	3·33	0·50	65
4	12/42	7	9·86	17·43	0·71	3·86	0·57	65
5	12/23	8	10·88	19·75	..	2·88	0·75	66
6	12/25	10	10·50	19·10	0·40	2·70	0·90	66
7	12/26	6	10·17	18·67	0·84	2·50	1·00	66
8	12/38	5	10·20	20·20	..	2·60	0·80	66
9	12/10	7	10·57	17·00	1·29	3·15	1·00	67
10	12/30	7	10·14	17·71	..	3·86	1·00	67
11	12/45	5	7·40	18·80	..	4·60	0·60	67
12	12/2	8	10·75	18·50	1·25	3·00	0·75	68
13	12/3	5	11·00	19·40	0·40	2·80	1·00	68
14	12/14	3	10·00	19·00	..	3·50	1·00	68
15	12/17	1	9·00	15·00	1·00	5·00	1·00	68
16	12/27	7	11·43	19·30	0·51	2·71	0·86	68
17	12/28	5	10·20	19·80	0·40	3·00	0·80	68
18	12/9	4	11·00	18·75	..	3·25	1·25	69
Mean conjugation in B_1 individuals with the same (2n) chromosome numbers		20	11·28	18·48	0·22	3·11	0·68	65
		29	10·44	19·43	0·31	2·67	0·86	66
		19	9·37	17·84	0·43	3·87	0·87	67
		29	10·40	18·50	0·59	3·33	0·90	68
		4	11·00	18·75	..	3·25	1·25	69

It will be seen from Table I that the chromosome numbers of individual plants in the backcross population occur as 65 + 1 to 4, which is in conformity with their allo-pentaploid constitution (AA DD B). During meiosis, univalent and multivalent associations of 2, 3, 4 and 6 chromosomes appeared in variable proportions. Majority of chromosomes associated as bivalents. The mean number of trivalents and hexavalents showed a progressive increase with increase in chromosome number from 2n=65 to 69. This possibly indicates that the supernumerary chromosomes which were in excess of the normal pentaploid complement of 65, mostly participated in such tri-and hexavalent associations. Quadrivalents and hexavalents showed chromatin bridges during their anaphasic separation (Plate VII, figs. 4-5; Plate VIII, figs. 6-7). Number of univalents varied over a narrow range from 9 to 11 per P.M.C. in most cases except in pot-culture 12/6 where their mean number is too high (15·25) and in pot-culture 12/45 where it is too low (7·40). Univalents could be easily distinguished from the rest of the chromosomes at m-phase due to their darker staining, relatively larger size and random orientation in a scattered manner outside the main group of conjugated chromosomes at m-phase. It appears, that they undergo comparatively less linear contraction and therefore, their individual morphological features such as satellites or constrictions were sometimes more clear than in the rest of the chromosomes (Plate VII, figs. 1-5; Plate VIII, figs. 6-8). Throughout anaphase and telophase of the first division, these univalents either remained static at the positions originally occupied during m-phase or moved at random and lagged behind. As a result of this, in addition to the two major groups of separating chromosomes, there were also minor groups at ana and telophases formed by the incorporation of the scattered univalents (Plate IX, fig. 9). These groups gradually lost their chromaticity during interphase and again reappeared at the second meiotic division (Plate IX, fig. 10). Analysis of 14 pollen mother cells taken from 10 different pot-cultures showed at telophase I or metaphase II, the following distribution of chromosomes in groups (Table II).

TABLE II

Chromosome grouping at first telophase or second m-phase

Serial number	Number of groups	Number of chromosomes in each group	Total (2n)
1	3	38+26+3	67
2	3	33+31+3	67
3	3	34+29+4	67
4	3	39+26+1	66
5	3	39+26+1	66
6	4	33+32+2+1	68
7	4	29+28+6+4	67
8	5	33+23+5+4+3	68
9	5	34+31+2+1+1	69
10	5	28+27+5+5+3	68
11	5	30+29+6+2+1	68
12	6	32+28+2+2+1+1+1	66
13	7	30+27+3+2+2+1+1	66
14	7	28+26+6+2+1+1+1	65

As shown in Table II, the number of major and minor groups varied from 3 to 7. Univalents in the minor groups frequently showed precocious longitudinal split (Fig. 9). There was also precocious deposition of cell wall round some of the minor groups which process might begin at late anaphase or early telophase of the first division (Fig. 9). In the case of the two major groups of previously conjugated chromosomes, such wall was seen deposited usually after the completion of the second meiotic division. As a result of such internal free cell formation, there were usually four microspores of normal size together with a variable number of abnormally small micronuclei enclosed within the wall of the same pollen mother cells (Figs. 11 to 17). Table III gives the frequency of P.M.C. with different numbers of micronuclei.

Table III

Frequency of P.M.C. containing microspores + micronuclei

Number of microspores + micronuclei per pollen mother cell	1	2	3	4	5	6	7	8	9	10	11	
Number of P.M.C.	2	8	24	146	92	72	68	30	10	5	1	*Total*=458

The number of microspores+micronuclei per P.M.C. therefore, varied from 1 to 11, modal value corresponding to 4. The resulting pollen grains showed corresponding range of variation in their size from large to small with intergrades (Fig. 18).

The plants of the first backcross generation gave only a stray setting of bolls and these in turn contained only a few healthy seeds. About 45 seeds thus obtained were sown in the next season and the progenies were under further observation.

Interpretation

Synthetic hexaploid [AA DD BB], the seed parent in the cross from which the first backcross individuals were derived, gives more or less uniform (ADB) gametes due to regular autosyndetic pairing of the identical duplicated chromosomes [Beasley, 1942, Iyengar, 1944]. Co2, the pollen parent, is also relatively homozygous, having been isolated by pure line selection. This possibly explains the absence of any wide range in morphological variations among the backcross individuals studied here. The hexaploid (AA DD BB) shows slight meiotic irregularities by way of rare univalent and multivalent associations [Beasley, 1942 ; Iyengar, 1944]. These small meiotic irregularities may be responsible for the slight variation in chromosome numbers of the backcross individuals within a close range of (65 + 1 to 4).

Since the allopentapliod backcross individuals have the genomic constitution (AA DD B), theoretically their meiotic conjugation should consist of 26 bivalents and 13 univalents (13 pairs of AA — 13 pairs of DD + 13 chromosomes of B set

appearing as univalents). It will be seen from Table I that the expected number of univalents was nearly realised in some cases but in other respects the actual mode of conjugation considerably deviates from the theoretical expectations due to formation of multivalents. Trivalents and quadrivalents may be formed as a result of allosyndesis due to expression of partial homologies between A, B and D sets. This has been reported in interspecific *Gossypium* hybrids of the type AB, BD and AD by several authors. In the case of backcross individuals with more than 65 chromosomes, hexavalents may be formed due to conjugation of supernumerary homologues. But such hexavalents have been observed even in the case of individuals with 65 chromosomes (Table I). Association of 6 chromosomes in such cases is difficult to understand but it can be explained in the light of the following facts which have been so far observed.

(1) Chromosomes of *Gossypium* may show intrahaploid pairing under abnormal conditions of meiosis [Skovested, 1933 ; Webber 1938 ; Beasley, 1942].

(2) Cultivated amphidiploid cottons (AADD) rarely show small proportion of quadrivalents due to allosyndetic pairing between A and D sets [Webber, 1934].

(3) A and D sets do not ordinarily pair with each other but both of them can pair with B to a variable extent [Skovested, 1937; Webber, 1939; Silow, 1941].

B-chromosomes of *anomalum*, therefore, act as a bridging link between A and D chromosomes so that all these three sets may occasionally enter into multivalent associations. Formation of hexavalents can, therefore, be explained as a result of possible operation of one or more of these factors. The fact that chromatin bridges are formed during their anaphasic separation, supports the above explanation since it implies that the chromosomes participating in such multivalent associations are not identical in all respects but have undergone considerable linear differentiation through inversions and other forms of structural changes.

Formation of micronuclei through internal free-cell formation may lead to interesting consequences. It has the effect of isolating abnormal univalents possibly from B set and prevent them from getting mixed up with other chromosomes that have undergone pairing. Such elimination may result in correspondingly minimising the irregularities of the gametes that have developed from the paired chromosomes, and thus render them less non-functional. Partial seed-setting obtained on these sterile allopentaploids may perhaps be attributed to chance fusion of such less irregular gametes.

Discussion

Individual plants in the first backcross generation have been again backcrossed to the *hirsutum* parent and this process will be continued until chromosomally balanced types combining the desirable economic qualities are secured. In the light of the meiotic chromosome behaviour of the first backcross individuals studied here, we may expect the following results to occur in the course of such recurrent backcrossing :

(*a*) *Exchange of genes between A and D sets of cultivated New World Cottons (AA DD)*. A and D chromosome sets in the New World Cottons (AA DD) seldom show allosyndetic pairing so that chances of gene exchange among them are very remote. Since the B-chromosome set may partially pair both with A and D sets, it can serve as a medium to bring about such gene exchange between A and D sets, through its alternate pairing in successive generations. Such internal transfer of genes among A and D sets does not involve any quantitative change. But it may possibly lead to qualitative changes due to transfer of a few genes to new locations within the frame work of the same genomic constitution. The 'position effects' of similar nature are well known in the case of mutant 'Bar' genes in *Drosophila* [Sturtevant, 1925].

(*b*) *Transfer of anomalum genes to the genotype of the cultivated 52 chromosome cottons*. *Anomalum* genes may get transferred to A or D chromosomes or to both. Such transfer will be directly proportional to the number of AB or BD pairs formed and the frequency of chiasmata along these pairs. Skovested [1937] and Webber [1939] have studied the meiosis in hybrids of the type (AB) and (BD) and have found that the mean conjugation in the former is about 11 to 12 bivalents and in the latter about 5 to 6 bivalents. This implies higher affinity of *anomalum* B set to A than to D genome. Therefore, in the present case, where both A and D sets are available for pairing with B, there is relatively greater chance of *anomalum* genes being transferred to A set than to D. It will be seen from Table I that the mean number of univalents during meiosis is the highest (15·25) in the case of pot-culture 12/6 and lowest (7·40) in the case of pot-culture 12/45. This implies that the number of AB or BD pairs formed is minimum in the former case and maximum in the latter. On the basis of the above considerations, therefore, for the purpose of transference of *anomalum* genes to the *hirsutum* cottons, there is greater chance of success being achieved if we use a type like 12/45 showing more pairing instead of a type like 12/6 which shows less pairing. As regards the possible factors which may be responsible for such minor plant to plant variations in the degree of pairing in a population having the same genomic constitution (AA DD B), we can only surmise. There are many instances of synthetic hybrids and polyploids of *Gossypium* wherein the degree of meiotic pairing in materials with identical genomic constitution as observed by the same or different workers show considerable divergence. But the fact that such minor plant to plant variations exist in such populations, provides the possibility of utilizing them in a manner so as to serve the objective in view. Perhaps it is such variations which provide scope for continuous selection in the successive generations of synthetic autotetraploids [Frolova, 1946] or in synthetic allopolyploids containing homologous chromosomes in multiples [Armstrong *et al* 1947].

(*c*) *Substitution of A and D chromosomes by their homologues from the anomalum B set*. Since AB or BD pairs have random orientation during anaphasic separation, we cannot expect all the B chromosomes in such pairs going to one pole and their counterparts going to another. This must, therefore, lead to formation of some 26 chromosome gametes wherein some of the A or D chromosomes may be replaced by their B homologues. Chance fusion of such gametes may lead to formation of 52

chromosome cottons wherein a few of the members of the normal (AA DD) set may be substituted by their homologues from *G. anomalum*.

(*d*) *Addition of anomalum chromosomes to the* (*AA DD*) *complement of cultivated tetraploid cottons.* General course of meiosis in the first backcross individuals described before is such that it is likely to form some gametes having full AD complement plus one or more univalents from the B set. Chance fusion of such gametes will give individuals having (1) full (AA DD) complement plus *anomalum* single chromosomes, (2) full (AA DD) complement plus *anomalum* chromosomes in homologous pairs. It has been stated before that as a result of stray setting on the 19 first backcross individuals, 45 seeds have been secured. These seeds when germinated should give rise to plants of both the types under (1) and (2) specified above. Seeds obtained as a result of second backcrossing to *hirsutum* can only give rise to individuals of the type (1) specified above and at least one generation must intervene before the single *anomalum* chromosomes can appear as homologous pairs through selfing.

In the course of such recurrent backcrossing, one or more of the possible changes described above, may occur either separately or all together. There is every possibility of changes under (A) taking place but it will not be possible to study these changes individually in isolation due to difficulties involved in this case, of distinguishing such 'position effects' from other concurrent effects due to the added *anomalum* genes. Changes taking place under (B) are likely to be of most practical utility. If a stable and well balanced type is to be aimed at as a final product, all that can be expected from such wide interspecific crosses is the transference of a few desirable genes which can be harmoniously incorporated into the genetic frame work of the recurrent parent. Any of the *anomalum* chromosomes may pair either with A or D or both and yet it may not be possible to effect the transfer of some of its desirable genes if they are located at such loci along the length of pairing chromosomes where crossingover is impossible. In such cases *anomalum* characters can be incorporated in the recurrrent parent by substituting A or D chromosomes by their B homologues carrying the desired genes as described under (C). In such interspecific differences, however, homology of the substituted chromosomes does not imply its genetic identity with the original chromosomes so that the former cannot be harmoniously incorporated within the genomic framework of the recurrent parent without disturbing its initial specific balance. This situation sometimes leads to either gametic or zygotic elimination of the substituted chromosomes [East, 1927]. In such an event, the only way to incorporate the desirable *anomalum* characters in the recurrent parent is by the addition of *anomalum* chromosomes in homologous pairs as described under (D).

Such 'alien substituted races' and 'alien addition races' described under (C) and (D) respectively, have been already obtained in the case of wheat, tobacco and a few other crops [Kattermann, 1938; Nishiyama, 1939; O'mara, 1940; Gerstel, 1945; Clayton, 1947, etc.]. Gerstel [1945] succeeded in adding an entire chromosome pair from *Nicotiana glutinosa*, carrying resistance to the mosaic virus disease, to the unaltered complement of *N. tabacum*. In a similar manner, Clayton [1947] succeeded

in evolving cultivated tobacco, resistant to the severe bacterial disease (wild fire) caused by *Pseudomonas tabaci* and *P. angulata*, by using the wild species *N. longiflora* which carries immunity genes. Many of these synthetic types are meiotically stable and true-breeding and are, therefore, useful as breeding stocks for the improvement of cultivated forms. Therefore, such synthetic derivatives with substituted or added chromosomes have not only theoretical value but practical utility as well.

By using the first backcross individuals studied here as pollen parents and *G. hirsutum* (Co2) as seed parent, a second backcross population was raised to maturity during the current season. Cytological study of these second backcross individuals has shown that they actually contain one to three *anomalum* chromosomes ($2n=52+1$ to 3) which could be identified either as substituted or added, by their characteristic behaviour during meiosis. Since the study of this second backcross generation has revealed certain points of theoretical and practical importance, these results will be presented in detail later.

Cotton workers from Coimbatore and the Punjab in India have already proved the utility of *G. anomalum* for improving the economic characters in the cultivated *Arboreum* cottons ($2n=26$). But it is not yet known whether *G. anomalum* can be similarly utilised for the improvement of some of the economic characters in the cultivated New World cottons ($2n=52$). The present investigations are aimed at exploring the possibilities in this direction.

Summary

Synthetic hybrids and polyploids of *Gossypium* involving the African wild diploid species *G. anomalum* are remarkable in respect of rapidity of growth, vigour, healthiness and tolerance to some of the diseases and pests on cottons. Their fibre is strong, fine and lustrous with smooth, silky feel. With a view to transferring these economically useful characters to cultivated tetraploid cottons, a synthetic hexaploid [(*G. hirustum* × *G. anomalum*) F_1 Doubled] is being repeatedly backcrossed to the *hirsutum* parent.

The chromosome numbers in the first backcross individuals occur as ($2n=65+0$ to 4) as expected on the basis of their allo-pentaploid genomic constitution (AA DD B). In the case of individuals with normal pentaploid chromosome number ($2n=65$), the mean meiotic conjugation consists of 11·28 I + 18·48 II + 0·22 III + 3·11 IV + 0·68 VI. Among other contributary factors, formation of allosyndetic multivalents through the bridging influence of B chromosomes, possibly accounts for the discrepancy between the expected and actual modes of meiotic pairing. Multivalents show chromatin bridges during their anaphasic separation. Majority of the *anomalum* chromosomes appear as univalents scattered at random in isolated groups, each of which develops into a micronucleus, variable in size and number (1 to 11 per P.M.C.), by a process of internal free-cell formation.

In the course of recurrent backcrossing in the present case, following results may be expected :

(1) Exchange of genes between A and D sets of cultivated New World cottons (AA DD), through the bridging influence of *anomalum* B chromosomes.

(2) Transfer of *anomalum* genes to A and D chromosomes.

(3) Substitution of A and D chromosomes by their homologues from the *anomalum* B set.

(4) Addition of *anomalum* chromosomes to the (AA DD) complement of cultivated tetraploid cottons.

These possibilities are discussed in short in the light of the meiotic chromosome behaviour of the first backcross individuals.

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References

Amin, K. C. (1941). Interspecific hybridization and colchicine induced polyploids in cottons. Second conference on cotton growing problems in India. *Genetics and Plant Breeding,* paper No. **5**

Anson, R. R., Knight, R. L. and Evelyn, S. H. (1946). Progress report of the Plant-breeding Station, Anglo-Egyptian Sudan, 1944-45. *Plant Breeding Abs.* **16**, 393

Armstrong, J. M. and Stevenson, T. M. (1947). The effect of continuous line selection in *Triticum agropyron* hybrids. *Emp. J. of Expt. Agric.* **15** : 51—64

Beasley, J. O. (1942). Meiotic chromosome behaviour in species, species hybrids, haploids and induced polyploids in cotton. *Genetics* **27**, 25—54

Beasley, J. O. and Richmond T. R. (1943). Cytogenetics and improvement of cotton. *Emp. Cot. Gr. Rev.* **20**, 54

Clayton, E. E. (1947). A wild-fire resistant tobacco. *J. Hered.* **38**, 35—40

East, E. M. (1927). A study of partial sterility in certain hybrids. *Genetics* **6**, 311—365

Frolova, S. L. *et al* (1946). Cytological basis of high fertility in autotetraploid Buckwheat. *Nature* **158**, 520

Gerstel, D. U. (1945). Inheritance in *Nicotiana tabacum*. XIX. Identification of *Tabacum* chromosomes replaced by one from *N. glutinosa* in mosaic resistant Holmes Samson tobacco. *Genetics* **30**, 448—454

Gerstel, D. U. (1945). Inheritance in *Nicotiana tabacum*. XX. The addition of *N. glutinosa* chromosomes to tobacco. *J. Hered.* **36**, 197—209

Iyengar, N. K. (1944). Cytological investigations on hexaploid cottons. *Ind. J. agric. Sci.* **14**, 142—151

Kattermann, G. (1938). Uber konstante halmbeharte stame aus Weizenroggenbastardierung mit 2n=42 chromosomen. *Zeits. Indukt. Abstams. Vererb.* **74**, 1—16

Margabandhu, V. (1941). Preliminary studies on pests of wild cottons. Second conference on cotton growing problems in India. *Cotton Pests and Diseases,* paper No. 6

Nishiyama, I. (1939). Cytological studies in *Avena.* III. Experimentally produced eu and hyperhexaploid aberrents in oats. *Cytologia* **10**, 101—104

O'Mara, J. G. (1940). Cytogenetic studies in *Triticale.* I. A method for determining the effects of individual *Secale* chromosomes on *Triticum.* *Genetics* **25**, 401—408

Patel, G. B., Thakar, B. J. and Deodikar, G. B. (1946). Some considerations on interspecific hybrids and polyploids in cotton. Third conference on cotton growing problems in India. *Genetics and plant Breeding,* paper No. 8(a)

Silow, R. A. (1941). The comparative genetics of *Gossypium anomalum* and the cultivated Asiatic cottons. *Mem. Cot. Res. St.* Trindidad, **A**—**17**

Skovested, A. (1933). Cytological studies in cotton. I. The mitosis and meiosis in diploid and triploid Asiatic cottons. *Ann. Bot.* **47**, 227—251

Skovested, A. (1937). Cytological studies in cottons. IV. Chromosome conjugation in interspecific hybrids. *J. Genet.* **34**, 5—42

Sturtevant, A. H. (1925). The effect of unequal crossing-over at the Bar locus of *Drosophila.* *Genetics* **10**, 117—147

Webber, J. M. (1934). Chromosome number and meiotic behaviour in *Gossypium.* *J. agric. Res.* **49**, 223—237

Webber, J. M. (1938). Cytology of twin cotton plants. *J. Agr. Res.* **57** : 123—138

Webber, J. M. (1939). Relationships in the genus Gossypium as indicated by cytological data. *J. agric. Res.* **58**, 237—261

INVESTIGATIONS ON THE 'BAD OPENING' OF BOLLS IN SIND-AMERICAN COTTONS IN SIND

I. CAUSES AND THE REMEDIAL MEASURES FOR BAD OPENING*

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WITH the introduction of perennial irrigation in Sind after the construction of the Lloyd Barrage in 1932, the acreage under American cotton crop in Sind had considerably increased, so much so that nearly 90 per cent of the total cotton crop of 8,44,597 acres in 1946-47 was American. The cotton area in Sind can be divided into three tracts on account of small differences in the climatic conditions prevailing in each ; (i) the South and East tract comprising of Tharparkar and lower half of the Hyderabad district ; (ii) the Middle Sind comprising of Nawabshah district and (iii) the North Sind comprising of Larkana district and some parts of Sukkur district. Of the three tracts, the first two are situated on the left bank of the Indus river, while the third tract is on the right bank. The first was by far the most important cotton tract where major portion of the total American cotton crop was grown.

There are small but important differences in the climatic conditions in these tracts. South and East Sind are characterized by a milder climate than the Middle and the North Sind. In the South and East Sind the temperatures are as high as in the Middle or the North Sind during the months of April and May, but they drop appreciably towards the end of June in the South Eastern parts as compared with the temperatures prevailing in the other two tracts where high temperatures continue to prevail uptil September. The relative humidity during the day is also higher during the growing period in the South and East Sind than in the Middle and the North Sind Climatically the South and East Sind was, therefore, different from the other two zones, the latter resembling in climatic conditions the South-western tracts of the Punjab. The differences in climatic conditions in the three cotton growing areas of Sind were responsible for the differences in the sowing and harvesting time for the cotton crop. The crop was planted and harvested in the South and East Sind earlier than in the Middle and the North Sind or in the Punjab. The climatic conditions in the North Sind were still more severe than in the Middle Sind.

The Punjab-American varieties were first imported into Sind in 1923-24 and various selections were made of which 4F/98 and *Sind Sudhar* proved to be suitable

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for growing in Sind. These strains were given to the cultivators in 1933-34 and the acreage under these strains increased every year since then, with a consequent reduction in acreage under the *desi* types. Later on, another strain named M4 was produced at Mirpurkhas by pure line selection, from another Punjab-American strain called N. T. 21 and it entered into large scale cultivation in the year 1940. This strain was earlier in maturity, gave higher yield and lint out-turn but was coarser than *Sind Sudhar*. M4 has now become a popular strain with cotton growers in Sind.

The American cotton crop in Sind has been reported to suffer from two types of physiological diseases ever since it entered into large scale cultivation. These were 'bad opening' of bolls and the red leaf blight. The 'bad opening' of bolls indicated the prevalence of *tirak* as in the case of the Punjab-American cottons though the periodic failure of American cottons accompanied by intensification and spread of *tirak* as in the Punjab have not been reported from Sind. The 'bad opening' of bolls has been reported in the year 1932 by Barakzai [1938] in his Report of Sind Physiological Scheme which was partly financed by the Indian Central Cotton Committee.

It was, therefore, undertaken to investigate the causes that produced 'bad opening' of bolls and to remedy it by applying the same measures that were successful in the Punjab [1946]. The investigations on the red leaf disease have already been published [Dastur and Singh, 1947].

Investigation

Two soil types associated with 'bad opening' of bolls. During the cotton season of 1942 several fields were noticed in the different parts of Sind where the American cottons showed symptoms of 'bad opening' of bolls which contained immature seeds with poor quality of lint. The drooping and shedding of leaves in some fields were found to have been associated with 'bad opening' of bolls. These symptoms resembled *tirak* symptoms described for the Punjab-American cottons in the Punjab on soils with saline subsoil [Dastur and Singh, 1942] The yellowing and shedding of leaves was also a feature of the Sind-American cottons in Sind and these symptoms indicated light sandy lands deficient in nitrogen. It was, therefore, undertaken to determine, if the same two soil types, viz. (i) soils with saline subsoils and (ii) light sandy lands deficient in nitrogen, were associated with 'bad opening' of bolls in Sind as was found to be the case in the Punjab [Dastur, 1946].

Analysis of the soil upto a depth of six feet from fields, where drooping and the shedding of leaves accompanied by 'bad opening' of bolls was found to occur in different cotton tracts, was made and it was found that such fields contained abnormal quantities of soluble sodium salts in the subsoils as was the case in the Punjab. Results of soil analysis for two places are given below in Table I.

TABLE I

Soils with saline subsoils

	Nasirabad Estate (Kinjhejhi)					Cotton Botanist Farm (Mirpurkhas)						
Depth in feet	Total salts per cent	Soluble calcium per cent	Soluble sodium per cent	Exchange-able calcium m.e.	Exchange-able Na+K m.e.	*p*H	Total salts per cent	Soluble calcium per cent	Soluble sodium per cent	Exchange-able calcium m.e.	Exchange-able Na+K m.e.	*p*H
1st foot	0·063	0·011	0·006	10·8	1·4	8·3	0·080	0·013	0·006	8·4	0·8	8·1
2nd foot	0·096	0·015	0·014	11·6	1·4	8·2	0·256	0·024	0·048	7·6	1·4	8·0
3rd foot	0·162	0·023	0·033	10·8	1·6	8·1	0·454	0·025	0·146	6·0	0·4	8·0
4th foot	0·174	0·022	0·033	9·2	1·2	8·1	0·435	0·015	0·122	4·8	2·6	8·3
5th foot	0·330	0·031	0·046	6·4	1·0	8·0	0·497	0·017	0·132	4·4	3·2	8·2
6th foot	0·554	0·051	0·088	8·8	1·8	7·9	0·537	0·017	0·136	4·8	2·8	8·2

Soluble sodium was found to be higher than soluble calcium while exchangeable sodium was present in some cases but not in others. Similar results were obtained from the analysis of the soil samples taken from fields where *tirak* had occurred in other parts of Sind.

Light sandy soils were found to be widely distributed in Sind. In chemical and physical properties they resembled the light sandy lands met with in the Punjab [Dastur and Samant, 1942]. In many cases the clay fraction was lower than 10 per cent (Table II). Such light sandy soils were found to contain normal quantities of soluble salts in some cases while in some cases they were found to contain abnormal amounts of sodium salts. Thus, both *tirak* promoting conditions were also found associated together as in the Punjab.

TABLE II

Light sandy soils with normal subsoils

Depth in feet	Total salts per cent	Soluble calcium per cent	Soluble sodium per cent	Clay per cent	Silt per cent	Sand per cent
1st foot	0·063	0·010	0·008	7	14	76
2nd foot	0·060	0·010	0·007	11	17	72
3rd foot	0·068	0·009	0·005	9	26	64
4th foot	0·066	0·013	0·007	9	34	56
5th foot	0·093	0·014	0·007	15	39	45
6th foot	0·080	0·014	0·006	23	54	22

The crop on light sandy land showed premature yellowing and reddening of the leaves in the months of August and September. The red leaf blight generally developed on such lands and the investigations on this physiological 'disease' have already been described in a previous contribution [Dastur and Singh, 1947].

In addition to the above mentioned soil types found in Sind there were soils which contained a very high proportion of clay varying from 30 to 50 per cent different layers. Such soils were not found suitable for cotton growth as the crop remained small and stunted. These soils were also found unsaturated with bases.

Amelioration of ' bad opening ' of bolls. As late sowing was found to be a common remedy for *tirak* occurring on both soil types in the Punjab, [Dastur and Singh, 1940] it was undertaken to try out this measure to ameliorate ' bad opening ' of bolls occurring in the Sind-American cottons in Sind. It was necessary to arrange experiments on the two soil types in the different parts of Sind as the normal sowing period for cottons differed in the three different tracts. It was decided to go beyond the normal sowing period by about one month so as to determine the remedial effect of late sowing on the ' bad opening ' of bolls as compared with the ' bad opening ' occurring in the normally sown crop. Three to four sowing dates were, therefore, included as treatments in each experiment. M4, L. S. S. and *Sind Sudhar* were the three varieties normally grown in Sind and these were included in the experiments. Besides, the different Punjab-American cottons like 289F/K25, 289F/124 and 289F/199 were also included in some of these experiments. In some experiments laid out on light sandy lands the application of sulphate of ammonia was included as a separate treatment to study the remedial effect on ' bad opening ' of bolls of the application of sulphate of ammonia to light sandy lands. The effect of application of an extra irrigation during fruiting period to heavy sandy loams with saline subsoils on ' bad opening ' of bolls was also studied in some experiments in view of the results obtained in the Punjab [Dastur and Singh, 1940]. All experiments were designed employing modern technique as was done in the Punjab. The experiments were conducted during the period 1943 to 1946.

The boll weight determinations were made from randomised plants in each sub-plot of all the replicates at each picking. The boll weight results were statistically analyzed.

The boll weight determinations were made in 16 such experiments and the results of four of these experiments are given in Table III.

Cotton sowings in South and East Sind normally began by the third week of March and terminated by the end of April. So May and early June sowings along with March and April sowings were also included in the experiments conducted in this tract. It was found that later sowings gave significantly higher boll weight than the normal sowings (Table III), both at Kinjhejhi and Denisar Estate which were situated in the South Eastern parts of Sind. M4 strain gave significantly higher boll weight than *Sind Sudhar* or L. S. S.

The normal sowing period for the Middle Sind was between the middle of May and the middle of June ; so late-June and July sowings were included along with normal sowings in the experiments conducted in that tract. The results obtained in the two sowing date experiments conducted at Sakrand and at Pad Idan in this tract are given in the Table III. The end of June and July sowings gave significantly higher boll weights than the first two sowings at Sakrand. Similarly at Pad Idan the first two sowings suffered significantly more from ' bad opening ' of the bolls than the last two sowings.

TABLE III

The remedial effect of late sowing on tirak *as determined by the increase in weight of seed cotton per boll in gm.*

Experiment No. 7 — Kinjhejhi (1943)

Variety	Sowing dates				
	29 March	19 April	9 May	30 May	Mean (±0·048)
M4	2·45	2·84	3·25	3·71	*3·06*
Sind Sudhar	1·72	2·11	2·05	2·79	*2·17*
L. S. S.	2·24	2·39	2·49	2·92	*2·51*
Mean (±0·062)	*2·14*	*2·45*	*2·60*	*3·14*	..

Experiment No. 2 — Denisar Estate (1943)

Variety	Sowing dates				
	2 April	23 April	16 May	3 June	Mean (±0·041)
M4	2·43	2·86	3·30	3·55	*3·04*
Sind Sudhar	2·57	2·74	3·15	3·25	*2·93*
L. S. S.	2·59	2·72	2·88	2·89	*2·77*
Mean (±0·072)	*2·53*	*2·77*	*3·11*	*3·23*	..

Experiment No. 24 — Sakrand (1943)

Variety	Sowing dates				
	14 May	3 June	24 June	17 July	Mean (±0·09)
M4	2·71	2·77	3·07	2·77	*2·83*
Sind Sudhar	2·20	2·22	2·33	2·71	*2·37*
289F/K25	2·72	2·61	2·98	2·82	*2·78*
289F/124	2·67	2·52	3·11	2·97	*2·82*
Mean (±0·11)	*2·57*	*2·53*	*2·87*	*2·82*	

Experiment No. 32 — Pad Idan (1946)

Variety	Sowing dates				
	22 May	7 June	22 June	7 July	Mean (±0·05)
M4	2·10	2·16	2·26	2·38	*2·22*
Sind Sudhar	1·24	1·62	1·80	1·99	*1·66*
Mean (±0·11)	*1·67*	*1·89*	*2·03*	*2·18*	

Amelioration of 'bad opening' by application of nitrogen. The effect of the application of nitrogen fertilizers on light sandy lands on the opening of bolls was studied in some of the experiments and it was found that manured plants produced better maturity of seeds than the unmatured plants.

The results of boll weights are given for the experiments conducted at Denisar Estate, Hyderabad and Sakrand in the following Table IV :

TABLE IV

The remedial effect of the application of sulphate of ammonia on 'bad opening' of bolls

—	Experiment No. 4 Denisar Estate (1944)		Experiment No. 18 Hyderabad (1944)		Experiment No. 26 Sakrand (1944)	
	Control	Manured	Control	Manured	Control	Manured
M4	2·42	2·60	3·17	3·26	2·83	3·06
L. S. S.	2·28	2·40	2·55	2·80	2·13	2·49
Sind Sudhar	2·06	2·14	2·52	2·72	2·22	2·65
Mean	*2·25*	*2·38*	*2·75*	*2·93*	*2·40*	*2·73*
S. E.	±0·06		±0·03		±0·06	

There was a significant increase in boll weight as a result of application of sulphate of ammonia indicating better maturity of seeds in the manured plots. It may be mentioned that 'bad opening' was generally more pronounced on soils with saline subsoils than on light sandy lands. As two sowing dates were included in the above experiments the results for the control and manured plots were an average of two sowing dates and consequently the ameliorative effect of later sowing has increased the boll weight in the control plots. If the results of control and manured plots of the first sowing are studies separately, the differences between the boll weights under two treatments would be still greater.

Amelioration of 'bad opening' by frequent irrigations. An experiment to study the effect of frequent irrigations during the fruiting stage on the 'bad opening' of bolls was conducted at Sakrand. The three watering treatments were W1=watering at 20 days' interval ; W2=watering at 15 days' interval and W3=watering at 10 days' interval. Three varieties M4, *Sind Sudher* and 289F/K25 were included in the experiment. The results of boll weights are given in Table V.

TABLE V

Weight of seed cotton per boll in gm.

—	Watering at an interval of			Mean (±0·44)
	20 days	15 days	10 days	
M4	3·30	3·08	3·42	3·26
Sind Sudhar	2·89	2·93	3·12	2·98
289F/K25	3·21	3·13	3·66	3·33
Mean	3·14	3·05	3·40	..

Watering at an interval of ten days had significantly increased the boll weight.

Results of all experiments on amelioration of 'bad opening'. The results of the mean weights of seed cotton per boll in gm. under different sowing dates averaged over all other treatments along with standard errors for the 16 complex experiments conducted from 1943 to 1946 are given in the following Table VI. A study of the results will show that there was a progressive increase in the weight of seed cotton per boll as the sowing was done later in each tract of Sind indicating 'better opening' of bolls. In experiment No. 19 conducted at Hyderabad the boll weights under all the four sowing dates were nearly the same indicating normal opening under all sowings.

TABLE VI

Mean weight of seed cotton per boll in gm. under different sowing dates

Experiment number.	Place	Year	Sowing dates				S.E.
2	Denisar Estate	1943	2 April	23 April	16 May	3 June	
			2·53	2·77	3·11	3·23	±0·072
3	do.	1944	25 March	15 April	4 May	25 May	
			1·60	1·89	1·95	2·04	±0·68
4	do.	1944		18 April		22 May	
				2·21		2·42	±0·061

TABLE VI—*contd.*

Mean weight of seed cotton per boll in gm. under different sowing dates

Experiment number	Place	Year	Sowing dates				S.E.
6	Denisar Estate	1946	1 April 2·28	15 April 2·40	30 April 2·51	15 May 2·69	±0·068
7	Kinjhejhi	1943	29 March 2·14	19 April 2·45	8 May 2·60	30 May 3·14	±0·062
8	do.	1944	8 April 2·38	26 April 2·64	15 May 2·79	3 June 2·92	±0·076
12	Mirpurkhas	1943	9 April 1·73	30 April 2·10	20 May 2·90	10 June 3·23	±0·074
18	Hyderabad	1944		22 April 2·70		22 May 2·98	±0·035
19	do.	1944	17 April 2·94	7 May 2·85	3 June 2·86	24 June 2·90	
20	do.	1945		30 April 2·84	21 May 3·04	11 June 3·68	
21	do.	1946	15 April 2·56	30 April 2·67	15 May 2·71	30 May 2·85	±0·069
24	Sakrand	1943	14 May 2·57	3 June 2·53	24 June 2·87	17 July 2·82	±0·11
25	do.	1943	22 May 2·85	10 June 3·28	3 July 3·39	22 July 3·26	

TABLE VI—*contd.*

Mean weight of seed cotton per boll in gm. under different sowing dates

Experiment number	Place	Year	Sowing dates				S.E.
26	Sakrand	1944		25 May	.	25 June	
				2·44		2·69	±0·068
29	do.	1946	18 May	3 June	22 June	8 July	
			2·25	2·45	2·45	3·01	
32	Pad Idan	1946	22 May	7 June	22 June	7 July	
			1·67	1·89	2·03	2·18	±0·11

SUMMARY

Investigations were conducted in Sind to determine the causes of the 'bad opening' of bolls containing immature seeds and weak fibre in the Sind-American cottons and to remedy it by applying the same measures that were successful in remedying *tirak* in the Punjab-American cottons in the Punjab.

The same two soil types (i) soils with saline soils and (ii) light sandy lands deficient in nitrogen were found to be associated with the 'bad opening' of bolls, as was the case in the Punjab. Drooping of leaves on the first soil type and the yellowing and subsequent reddening of leaves on the second soil type were also found to occur.

The application of sulphate of ammonia to light sandy lands and of frequent irrigations to soils with saline sub-soil was found to remedy immaturity of seed and lint. The late sowing was, however, found to be a common remedy for 'bad opening' on both the soil types.

The results of 16 multifactor experiments conducted in different parts of Sind are given to show the ameliorative effect of late sowing on the 'bad opening' of bolls as measured by the boll weight method.

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REFERENCES

Barakzai, M. U. (1938). Cotton Agronomy; First conf. Sci., Res. Workers in India. *Indian Cent. Cott. Comm.* Bombay

Dastur, R. H. (1946). The periodic partial failures of the American cottons in the Punjab their causes and remedies. *Si. Monograph* (2) *Ind. Cent. Cott. Comm.* Bombay

Dastur, R. H. and Singh, Kanwar (1947). Investigations on the red leaf disease in American cottons. I-Red leaf disease in Sind-American cottons in Sind: *Indian. J. Agric. Sci.* **17**

Dastur, R. H. and Singh, Mukhtar (1942). Studies in the periodic partial failures of the Punjab, American cottons in the Punjab-VII-Amelioration of *tirak* on soils with saline subsoils (sandy loams). *Indian. J. Agric. Sci.* **12**, 679—695

Dastur, R. H. and Samant, K. M. (1942). Studies in the periodic partial failures of the Punjab-American cottons in the Punjab-V.Physical and chemical properties of the soil associated with *tirak*. *Indian. J. Agric. Sci.* **12**, 474—492

THE PROSPECTS OF INDIA RUBBER AND PARA RUBBER IN INDIA

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(With Plates X-XIV and five text-figures)

RUBBER was considered to be one of the most precious articles of commerce in the last global war for obvious reasons. During the latter period of the war, the allied nations felt extreme scarcity of Para rubber because of the fact that the largest rubber producing areas soon came under the occupation of the Japanese.

In 1940 shipments in long tons from the occupied areas and the percentages of world shipments were—Malaya : 540,417 or 38·9 per cent, Indo-China : 64,437 or 4·6 per cent ; Siam : 43,940 or 3·2 per cent ; Sarawak and North Borneo : 52,789 or 3·8 per cent. This loss leaves a gap on the basis of the estimated 1941 import requirements of about 130,000 tons which could be covered without difficulty by greater use of reclaimed rubber and the development of existing synthetic production in the U. S. A.*

With the occupation of Sumatra and the rest of Borneo by the Japanese the rubber position was serious. In 1940 shipments from Sumatra and Borneo accounted for 80 per cent, and from Java for 20 per cent, of the Netherlands East Indies, total production of 536,740 tons. This loss of an additional 38·6 per cent increased the gap to about 670,000 tons or on the basis of the 1941 quotas, to 800,000 tons.*

Conditions deteriorated still more when all the British plantations in South Burma were also occupied by the Japanese. Frantic attempt was, therefore, made by the allied nations to replace the shortage in the supply of rubber for various war purposes. Researches for the production of synthetic rubber were carried on vigorously and all kinds of rubber yielding plants were the subject of investigation. In the Jodrell Laboratory at Kew, the rubber contents of *Taraxacum Kok-Saghys* and in India of *Cryptostigia grandiflora*, an ornamental spreading shrub, imported to India from the tropical Africa, received particular attention. The India rubber tree (*Ficus elastica*) of which there are many a legend about its rubber yielding capacity also formed. like that of *Cryptostigia grandiflora*, subject of careful consideration.

Ficus elastica—*the India rubber tree—its possibilities as a source of rubber*

The writer in full agreement with Mr. I. H. Burkill is not at all hopeful about the prospect of utilizing rubber from these two species on account of the poor quality and yield, with high resin contents of their latex. Nevertheless, much bootless efforts were made in some parts of India towards large scale cultivation and manufacture of rubber from *C. grandiflora*.

* Amrita Bazar Patrika notes on rubber market (London correspondent of Partika, 1942).

Attention was also focussed on two plantations of India rubber trees in the Sikkim State. These were started some 50 years ago by some unknown German planter. Most of these trees have reached yielding capacity a few years ago. I have studied these plants both at Mangbar (Plate XI, fig. 3) and higher up at Ranikhola forest blocks along either sides of the Lachen-Gangtok trade route which leads to Tibet across the high mountains of East and North Sikkim. I have also had the opportunity to study the vast rubber plantations and factories in Tennasserim, Mergui District of South Burma consecutively for three years from 1930 to 1932, and discuss various horticultural and economic aspects of the true rubber trees with the experienced planter, Mr. G. A. M. Forbes, of the Mergui Rubber Plantation and Mr. I. A. Ford of Tennasserim Rubber Plantations (Plates X and XI, fig. 2).

Conditions of rubber plantations in South Burma were extremely disappointing at that time when the price fell to 3 annas per lb. and Mr. Forbes once a rubber prince in that part of the world ran short of funds even to keep the plantations in proper order. Nearly all the plantations were then left untapped due to the slump in the rubber market. I have thus been able to form some idea about the prospect of the two rubber yielding plants, *Hevea brasiliensis*, the true Para rubber trees, and *Ficus elastica*, the India rubber trees, which have recently been studied. In the present paper I have briefly recorded my observations on these two rubber yielding plants together with my views on the complicated economic question concerning cultivation and future position of rubber in the world market.

Experimental cultivation of India rubber in India

In the Mangbar block about 66 acres are under *Ficus elastica* plantation Records so far available show that the trees were planted some time between 1902 and 1911. The plantation extends over nearly a couple of miles on either side of the Lachen Road. There were approximately 60 to 80 plants per furlong in the area (Plate XI, fig. 3).

The Ranikhola block forms a much smaller compact patch of several hundreds of trees further higher up the road spreading over more exposed hill sides. These trees are comparatively younger and they were found to be not so much subjected to tapping as those of the Mangbar plants (Plate XIII, fig. 5).

The India rubber tree *Ficus elastica* of the family of *Urticaceae* seems to grow naturally in these forests, sometimes starting life as an epiphyte like *Ficus benghalensis* and *Ficus religiosa*. The trees are very large with rather widely spreading branches and a number of cord like aerial roots hanging downwards from the branches close to the trunk. Thick buttressed roots sometimes extend over the surface of the ground all round the base of the tree. All parts of the tree are covered with brownish grey glabrous bark. Leaves are 6 to 10 inches $\times$ 2 to 3 inches large, coriaceous, shining above, oblong-elliptic with a short petiole and a very prominent thick midrib (fig.1). The trees measure about 40 to 120 ft. in height and about 6 to 15 ft. in girth. Tropical and sub-tropical rain-forest zone is the favourite habitat of the species. Hence this caoutchouc yielding fig tree is seen in abundance in the Terai forest of Sikkim, Assam, Burma and Malaya extending from the base of the Eastern Himalaya to Ceylon, Malaysia and islands in the Far East. The

FIG. 1. A portion of the Para rubber plantation in Mergui, South Burma, showing the nature of the bole and branching with a number of Burmese labourers of the plantation. The newly caught elephant with her young one is being domesticated and used for carrying fuel, removing logs and various other works. The writer is seen just behind the calf.

FIG. 2. A general view of the Tennasserim plantation of the *Hevea brasiliensis* showing the spacing of the trees and upkeep of the plantation.

FIG. 3. View of the Mangbar plantation of India rubber trees (*Ficus elastica*) on the Lachen Road to Gangtok, Sikkim, showing the nature of the trunk and branching which indicate how difficult it is to work with these trees.

FIG. 4. Showing the old incisions on the trees when rubber was extracted some years ago and also collection of latex by my Herbarium assistant, Sri Jogendra Nath Naskar from a newly made incision.

FIG. 5. Portion of India rubber plantation near Ranikhola further higher up on the Lachen Road. In the background is seen terrace cultivation of rice.

FIG. 1. *Ficus elastica* Roxb. Fruiting branch showing leaves and receptacles.

1. Vertical section of receptacle.
2. A male flower.
4 and 5. Gall flowers.
6. A male flower, the perianth being removed.
7. The same, the perianth being opened out and the anther removed.
8. Stipules.
9 and 10. Apex and base of receptacles respectively.

cultivation of the India rubber trees had, as reported by Brown, been started in 1914, in India at Kulsi and Charduar in Assam and on a smaller scale in Madras and Mysore and also in the Malaya Peninsula, Java and Sumatra. No accurate information, however, is available about the actual date of establishment of these two fairly large plantations. Records indicate that they were started during the early decade of the 20th century along these hill slopes of the Eastern Himalaya between an elevation of 1,000 ft. and 2,000 ft.

Cultivation.—The cultivation of the Indian fig rubber tree is very simple as it can easily be propagated from seeds, cuttings and layerings. It is advisable to raise the plants from seeds after treating them with the usual methods in the nursery. The seeds may be sown in boxes containing three parts of good soil and one part of leaf mould. The seeds germinate within five to fifteen days according to their viability and climatic and edaphic conditions. The seedlings when four to six inches high may be transferred to a protected, shady, well drained nursery bed and placed at a distance of one to two feet apart. When these are about three to six feet high, they may be planted in the open at a distance of 30 ft. apart and when sufficiently tall they may be thinned out and subsequently the plants may be allowed to grow 60 ft. apart. The fig rubber tree is a surface feeder hence in Assam they are sometimes planted, when 10 to 15 ft. tall, on a mound preferably on ant hills where the growth is faster than in the plain wasteland. In Assam, plantation records show that the tree grows to an average height of 22·5 ft. and average girth of 1·39 ft. in five years, and 85·0 ft. and 23·16 ft. in 24 years. The average annual rate of growth during 24 years of trees after planting in the open at Charduar, Assam, was about 3·38 ft. in height and 0·99 ft. in girth. Table I illustrates yield of rubber in Assam plantation.

TABLE I

Yield of rubber in Assam plantation

	Area tapped in Acres	Number of trees tapped	Yield of rubber		
			Total lb.	Per tree lb.	Per acre lb
Charduar—					
1907-8	642	8,265	8,346	1	13
1908-9	417	4,734	7,560	1·6	18·1
1909-10	348	5,542	12,971	2·3	37·3
1910-11	336	4,327	9,087	2·1	27·0
Kulsi—					
1907-8	88	2,087	4,083	2	46
1908-9	66	3,955	2,573	0·65	39
1909-10	88	1,477	3,240	2·2	36·8
1910-11	66	..	..	0·9	52

'The trees at Kulsi are planted much closer than those at Charduar, and hence the yields per acre are higher.

In Cachar a number of trees tapped by making numerous small cuts with a chisel, gave the following results.

Eight trees planted in 1882 were tapped in 1905-6 and gave an average yield of 6 lb. of rubber per tree. The same trees tapped in 1906-7 gave an average of 5 lb. per tree, the individual yields varying from $2\frac{1}{2}$ lb. to 10 lb.

Four younger trees, planted in 1889-90, gave an average of about 2 lb. of rubber in 1905-6 and $2\frac{1}{4}$ lb. in 1906-7, the individual yields in the latter year being $1\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{2}$ and $3\frac{1}{2}$ lb. [Brown, 1914].

Coagulation of the latex of India rubber is variable and it coagulates quickly on exposure to light. The rubber is obtained often as scrap. Burgess recommmends the use of tannic acid as the best coagulant for *Ficus elastica* latex, and has proposed the following process. The latex, which should not be diluted with water, is warmed to 40° C., and a solution of tannic acid of known strength is then added until there is 1 per cent of tannic acid in the latex. Thus using a 20 per cent solution of tannic acid, one part of the solution would be added to nineteen parts of the latex. The latex is then gently churned, avoiding violent agitation, and in one or two minutes it sets to a cream and complete coagulation occurs' [Brown, 1914].

The following extracts from Burkill's *Dictionary of Economic Products of the Malaya Peninsula* on *Ficus elastica* as a rubber yielding plant in addition to my account of the India rubber tree supply a more less complete information on the cultivation and possibilities of this rubber yielding tree in India and the East.

> 'It has undergone a long trial in experimental cultivation as a source of rubber but has quite lost its place before *Hevea brasiliensis*, though a little rubber, is still got from it in Assam and Burma.
>
> 'The chief reason why it has lost its place is that there is a resin about 4 to 20 per cent, in the rubber, which hardening in course of time, annuls the elasticity.
>
> 'The leaves contain slime, which is not elastic (*Tropenpflanzer*, 1900, **4**, 230).
>
> 'Rubber from this fig appears to have been used in North-Eastern India for lining receptacles long before Europeans know anything about it. In 1810 Roxburgh received in Calcutta, from Assam, some honey in a rattan receptacle lined with it, and recognized that the material was like the caoutchouc of South America, which by then, from the custom of erasing pencil marks with it, had got the name of India rubber. Some years later a French miner working in Upper Burma, found it in use for lining baskets used for baling water.
>
> 'Knowledge that it could be obtained in Assam gradually spread ; soon after 1830 it entered into the export trade of Calcutta, and remained in demand for a short time ; but the trade gradually declined.
>
> 'When a Forest Department was formed in India, the India rubber from fig immediately came under study as a possible source of revenue. Its rubber appeared also in the markets of Java, Sumatra and Indo-China ; and a like

product in Malaya as well, the source of which was not discovered by Collins (*Rep. on Caoutchouc*, 1872, 22), but was made evident by Murton as *F. elastica* (*J. Roy. As. Soc. Straits Branch*, **1**, 1878, 107). .

Under the Indian Forest Department in North-Eastern India and contemporaneously in Java, planting was done. Very tardily Malaya followed suit' [Burkil, 1935].

The interest reached its peak in 1900 when simultaneous planting of Para rubber trees also started and soon after from 1906 to 1909 the interest was disappearing and in 1911 the cultivation of Para rubber in the east was abundant.

The India rubber fig may be tapped by incisions with a rest of about three months between each tapping. There is little in the method at all comparable with the method of tapping *Hevea* for rubber, and as a rubber-yielder the fig is far behind.

The age of the tree probably determines the amount of resin, old trees carrying less than young ones. Tapping begins at the age of five years. The yield is set down as increasing from 20 grammes of rubber per annum per tree to 250 grammes in the tenth year, and 1800 grammes in the eighteenth. In order to make room for growth the trees, originally rather thickly planted, have to be thinned to one-quarter. so the rate of increase per acre is far from being correspondingly rapid [Preuss in *Tropen-pflanzer*, **23**, 1920, 173]. One very old tree is said to have given at its first tapping 3 pikuls, or over 3½ cwt. of rubber [Reintgen in *Beihefte* 2/3 *zum Tropenpflanzer*, **6**, 1905, 197].

The latex is found chiefly in the inner bark, close to the cambium. The bark at this place is so constructed that on attempting to cut it with a tapping knife, it tears, being unequally firm ; this makes tapping as done with *Hevea* almost impossible. Instead. the bark is slashed or incised, and the latex allowed to coagulate, or to drop on to leaves spread below to catch it. The porduce is then like scrap rubber. The tapping may be done by incisions arranged in a hering—bone pattern for the convenience of getting the drops of latex to run together ; but the injury remains proportional to the number and length of the cuts, though these heal readily.

The latex in bulk coagulates uncertainly. The result of this was that all the earlier ' rambong ' collected came into the market as scrap. But when, about 1908 processes were devised for treating latex in various ways, with ammonia or tannin, a biscuit form appeared, as well as sheets and cakes. But by this time interest in it was disappearing [Burkill, 1935].

It is learnt that the trees of the Mangbar block were tapped, for the only time in the year 1943-44 and 408 lb. of rubber collected and sold to Messrs. Bata Shoe Company, Batanagar.

' V ' shaped scars of incision were observed all over the trunks and thick lateral branches of many large trees. Some of the main stems, large branches and buttressed roots were tapped too. The latex from all parts of the trees comes out almost immediately after the incision is made.

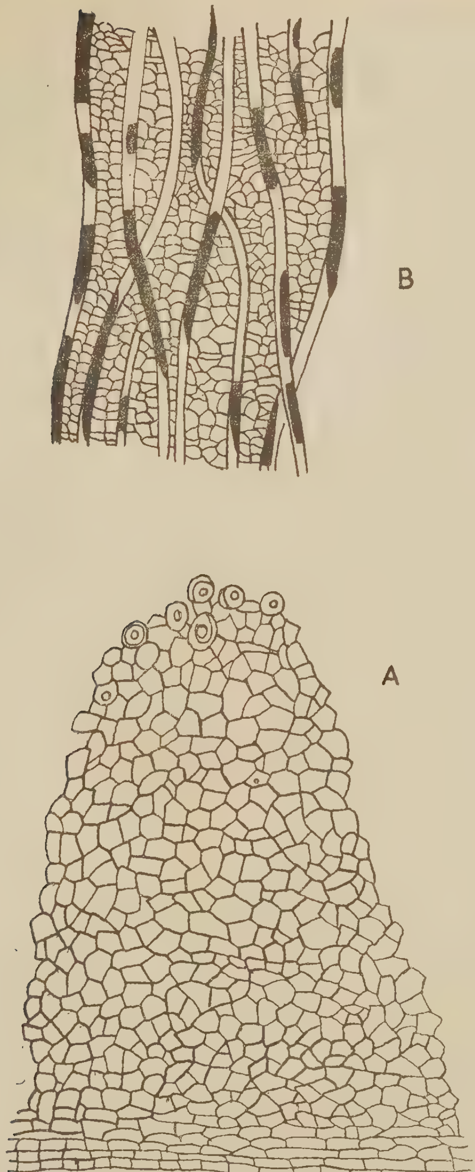

Fig. 2, A. Transverse section of bark of *Ficus elastica* (India rubber tree) showing the patches of laticiferous tubes filed with caoutchouc rubber (r).

Fig. 2, B. Longitudinal section of the bark of *Ficus elastica* (India rubber tree) showing the long laticiferous tubes blocked by patches of caoutchouc (r).

The bulk of the milk is collected from the main trunk and thick stout branches. Samples of latex were gathered from the trees growing in shade as well as in open sun light.

It was observed that the flow of latex was quicker in the plants growing in shade than those exposed to direct sun light. The rate of flow was about 1 oz., in 5 minutes. The optimum rate of flow of latex in the trees under the shade was found to vary between 15 seconds to 2 minutes after the incision was made. The rate of flow was found to be gradually reduced and after 10 minutes only a few drops came out at an interval of about five seconds and then the latex in the cut area began to coagulate. But in the plants growing in direct light, the latex coagulated within five minutes after the incision was made. The trees tapped are full grown trees about 40-45 years old (Plate XII, fig. 4).

In the transverse section of the bark of an adult tree of *Ficus elastica*, it was found that the laticiferous tubes were situated rather deeper on the inner side adjacent to the cambium layer and on the outer side below a layer of some 50 cells from the surface layer of the cork cells. The laticiferous tub ecan easily be distinguished from the other cells by the presence of coagulated rather pale brown rubber in them. In a longitudinal section laticiferous vessels were seen to form a richly anastomosing system extending below the surface layer of the cok throughout the entire length of the stem and the mature branches.

The laticiferous vessels are all fully developed and the maximum diameter of a tube is about 28 μ and the minimum about 16 μ (Fig. 2, A and B).

The chemical examination of the latex from India fig rubber trees of Mangbar block was carried out about two weeks after it was collected from the tree. It coagulated very rapidly after collection. It had a slight pinkish colour and a faint ethereal smell.

The results of the chemical analysis of the latex of India tubber trees are shown in the Table II.*

TABLE II

Results of the chemical analysis of the latex of India rubber

Rubber	Moisture	Total solid	Ash	Resin	Hydro-carbon	Total insoluble matter	Acid value	Nitrogen and protein
per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent.
60·78	19·21	80·79	2·555	8·824	824·45	89·12	38·64	0·5572

* Chemical analysis was carried out by Sri Promode Banerjee, M.Sc., Chemist under Rose Cultivation Scheme started under auspices of Council of Scientific and Industrial Research.

Comparison of some of the properties of *Ficus elastica* latex with those of *Hevea brasiliensis* latex is given below :

—	*Ficus elastica* per cent	*Hevea brasiliensis* per cent
Resin content	8·824	1·3
Nitrogen content	0·08915	0·4
Protein content	0·5572	2·5

The properties compare more favourably in the case of Assam and Madras plants as recorded by Brown and given in the Table III.

TABLE III

Comparison of Assam and Madras plants

Country	Description of rubber	Caoutchouc per cent	Resin per cent	Protein per cent	Insoluble matter per cent	Ash per cent
Assam—						
Charduar	Tree rubber	77·5	19·3	1·5	1·7	0·5
Kulsi	do	78·6	19·1	0·9	1·4	0.5
do	Mat rubber	81·9	16·2	..	1·9	1·9
Madras—						
Mukkie	Scrap	67·9	28·4	0·9	2·8	0·5
do	Biscuit	74·3	23·6	1·0	1·1	1·7
Madras—						
Parlakimedi	Cake	88·6	8·1	1·4	1·9	0·5

Conclusion

From the physical properties studied and the chemical data of the latex it is clear that it does not favourably compare with the Para rubber (*Hevea brasiliensis*). It may, however, be used when mixed up with Para rubber for the preparation of soles and heels of shoes and other articles in which block rubber is used.

Hevea Brasiliensis MUELL. ARG. (Para rubber tree)

History

The first systematic study of the South American rubber plants was made by Charles Marie de La Condamine as early as 1735 and in the year 1736, he handed over the specimens of rubber to the French Academy of Science stating that the product was obtained from a tree called '*Hevea*' by the natives in Ecuador [Brown, 1914].

But no further information about the botany of *Hevea* was obtained until 1865 when the genus was studied and described for the first time by J. Mueller and the tree which yields the famous Para rubber was named *Hevea brasiliensis* Muell. Arg. by him [Brown, 1914].

Previous to 1860 Para rubber was exported only in small quantities and it was not until 1876 when this rubber plant was introduced into Ceylon and Malaya from Sir Henry Wichham's collection of seeds from Rio Tapajo [Wright, 1905]. The first introduction of Para rubber in Mergui (Burma)was made in 1877 and in 1878 it was introduced into Madras [Wright, 1905].

First export of this rubber was made from Ceylon in the year 1884 [Wright, 1905] and from Malaya in 1899 [Burkill, 1935]. Definite records are available with regard to the collection of Para rubber in India and South Burma where, (Plate XIV, fig. 6) the trees have fully established and rubber was extracted uptil the year 1930. The 74 years old tree which was introduced to the Royal Botanic Garden in 1873 is still in perfect health in the Royal Botanic Garden, Calcutta. There is hardly any difference in growth and latex contents between this tree of lower Bengal and the tree of rubber plantation in Mergui, South Burma. The following extract gives the early history of introduction of Para rubber tree (*Hevea brasiliensis*) into India, Ceylon and Burma.

Bengal. 'It has been ascertained from the Superintendent of the Royal Botanic Garden, Calcutta, that nearly ten years ago a quantity of the seeds of this tree (one of the species from which South American India-rubber is obtained) was sent to the Royal Botanic Garden, Calcutta from Kew. Some of these seeds germinated, but it was found that the resulting seedlings were extremely sensitive to cold, and that the low temperature of the cold weather of Bengal proved fatal to them, even when planted in the most sheltered situations. Some of the seedlings were supplied to tea planters likely to give attention to their culture, and some were sent to Mr. Mann, the Conservator of Forests in Assam. The results obtained by these gentlemen were, however, the same as those obtained by Dr King and it was on his recommendation that subsequent supplies of *Hevea* seeds were sent to Ceylon, instead of to India. The Superintendent thinks that *Hevea* will grow well in Provinces like Malabar or Lower Burma, where the climate is said to be moist and equable, but in Northern India, where there is a distinct cold season, Dr King is of the opinion that cultivation is not likely to prove successful.

FIG. 6. The trunk of the *Hevea brasiliensis* in Tenasserim showing the newly made incisions at the base of the tree with the Ceylonese Officer and his Burmese wife and children. In the background is his bungalow mostly made of bamboo and cane.

FIG. 7. Portion of one of the largest rubber factories in Mergui—showing the latest aluminium tubs for treatment of latex, benches for spreading sheets of rubber and racks for drying sheets. In the centre is a girl holding two enamel buckets containing milky latex just collected from the trees. On the left hand side is Mr. G. A. M. Forbes (sitting) and the writer (standing).

'The Conservator of Forests, Bengal, who has also been consulted on the subject, reports that it does not appear that any experiment in the culture of the tree in question has ever been undertaken by the Forest Department in this Province'.

Burma. Colonel W. J. Seaton wrote of Tenasserim : 'Early experiments—Experiments on a small scale were commenced at Mergui in 1877, with eight seedlings, the survivors of a small batch received from Dr King, of the Botanical Gardens, Calcutta. They were successfully set out in the Forest office compound at Mergui, and although on a low hill, a not very desirable site, yet their growth was for some time satisfactory. In 1879, a large number of *Hevea* plants believed to be well rooted cuttings, were forwarded by Dr Thwaites, of the Royal Botanical Gardens, Ceylon and although in the charge of a subordinate who had been sent to Ceylon for special instructions, only 178 survived the voyage. These were set on low ground drained by the sources of the Boke Chaung, a small tidal creek. Only 64 of the healthiest plants survived the planting operation, and of these again casualties continued to take place yearly, owing chiefly to attacks of white ants until the number was reduced to 50 in 1886, since when there have been no further casualties' [Watt. 1890].

Description. A large tree attaining a height of 60 to 100 feet and a girth of 8 to 12 feet, leaves trifoliate with long petiole (3-4 in. long) ; leaflets 4 to 6 inches by $1\frac{1}{2}$ to $2\frac{1}{2}$ inches, ovate lanceolate, tapering at both ends. Flowers unisexual, small, green, in long panicles of variable length. Fruit a three celled triangular capsule each cell containing one oval seed with shiny testa (fig. 3). Flowering in cool season of January and fruiting in March and April. The fruits ripen in the rainy season in July and August.

Distribution. A native of South America and widely distributed in the Amazon and Orinoco river valleys introduced into all the tropical countries chiefly in India, Ceylon, Malaya, Java and Sumatra.

The following extract from Sir D. Brandis' review of Mr. Collins' report gives the tracts of India which Sir D. Brandis anticipated, and which all subsequent experience since 1873 has confirmed, as being most suited to Para rubber. Having compared the extremes of climate and also the means, on the west coast of India and Burma, with that of Brazil, he remarks : 'We may, therefore, conclude that Kanara, Malabar, Travancore, and the Burma coast, from Moulmein southwards, offer the desired conditions as regards temperature, for the successful cultivation of the caoutchouc-yielding species of *Hevea.* I would specially draw the attention of Forest officers in this respect to the moist, evergreen forests at the foot of the Coorg Ghats, and in Kanara, as well as to the Attaran valley and similar localities in Tennasserim' [Watt. 1890]. In fact large scale planting of *Hevea brasiliensis* as shade tree was successfully done in chinchona plantations of Tenasserim, Mergui, South Burma under the then Government of India during 1920 to 1930.

The climatic and edaphic factors prevailing in several parts of India indicate possibilities of large scale cultivation of Para rubber in India and in the hot and humid hilly regions particularly in the Chittagong Hill tracts, now Eastern Pakistan,

FIG 3. *Hevea brasiliensis* Muell. Arg.

1. A twig showing leaves and inflorescence
2. A female flower
3. A male flower
4. A fruit
5. Cross section of the fruit showing the seeds

Tripura in Bengal and across Manipur, Assam towards the north-east, and southwards to South Burma along Arakan Peninsula down to Tennasserim and Victoria Point in the south east, in addition to the present areas in Southern India and Ceylon which are now under cultivation of *Hevea brasiliensis*. The low hills of the Ganjam District, the lower seaside slopes of the Eastern and Western Ghats (REPORTED BY E. B. C. MODDER IN HIS No. 1414, as recorded in his herbarium specimens) and some of the suitable areas in the Duars and the Terai regions of the Eastern Himalayas may also be under experimental plantation with a view to meeting India's internal consumption of this valuable article required for various important industries. It is also expected that our leading scientists will be able to put a plant for the manufacture of synthetic rubber as well, and thereby supplement our total requirement of rubber in our country. The areas under cultivation of Para rubber and India rubber and possible areas for experimental cultivation of Para rubber are shown in a map of India (Fig. 4).

Cultivation of *Hevea brasiliensis*

I. *Climatic conditions. Hevea brasiliensis* can be successfully cultivated in those areas where there is a uniform and moderate temperature and sufficient rainfall throughout the year. The climatic conditions favourable to the cultivation of Para rubber are those as are prevalent in the Tropical Rain Forest areas.

II. *Soil.* For the best and quick growth of the trees, they should be planted in good alluvial soil wherever possible. The trees can also grow in swampy soil provided there is a thorough drainage system.

III. *Formation of plantation.* For the purpose of clearing the land the existing trees should be cut down and the timbers either disposed of or burnt as convenient be ; it is also advisable to remove the stumps of the trees from the soil in order to avoid the attacks of white ants and fungal infection on the rubber trees.

After the clearing of the land, roads and proper drainage are made and the entire plot is divided into blocks. Then holes of 2 ft. square and 1½ ft. deep are made for the reception of the rubber plants.

The Para trees are usually planted at intervals of 15 ft. by 20 ft. (about 150 trees per acre), 24 ft. by 22 ft. (about 150 trees per acre) or 20 ft. by 20 ft. (about 110 trees per acre). According to some, still wide planting (40 or 50 trees per acre) can bring about better results quickly than closely planted trees thereby attaining the required size for tapping more rapidly.

Raising of plants. The Para trees are generally propagated from seeds collected from eight to ten years old trees having a good yield. The plants are usually raised in nursery beds or in seed baskets and rarely seeds are planted 'at stake,' that is, in the position which the trees will occupy.

FIG. 4. Map showing the distribution and possible areas of cultivation of India rubber and Para rubber in India and her borders

The seeds are planted in rich soil in the nursery bed six to nine inches apart and one inch below the surface. The soil should be kept moist and the seedlings should be given proper shading against direct sunlight.

The seedlings are transplanted in the prepared holes when they are 2 ft. or 6 ft. high. In the latter case plants are lifted from the beds and after training the roots, these ' stumps ' are carried in bundles and then placed in the holes.

The seed basket method for raising the seedlings is highly recommended. Here the entire basket containing the seedling is placed in the hole without disturbing the plant.

As a rule transplanting should be done during rainy weather wherever possible.

Two or three seeds are planted simultaneously in the prepared holes in the case of ' at stake ' method of planting. When the seedlings have grown sufficiently the most healthy and vigorous in each hole is retained and the others are removed.

In places where there is a prolonged dry season, it is advisable to provide shade trees at least for the first two years [Brown, 1914].

' The trees grow rapidly, attaining some thirty feet in three years ; it is readily propagated by cuttings. Mr. Cross recommends plantations to be made in seasons of inundation or flood, the cuttings being forced into the mud for half their length, leaving enough above ground to save the tops from being actually submerged. Propagation by seed is not so successful ' [Watt, 1890].

Anatomy of Para rubber. In a native stem of *Hevea brasiliensis* the following tissues can be traced proceeding from the centre outwards—the pith, the wood, the cambium, the bast, the cortex and the bark. Only the cortex contains the latex tubes. The cortex is about 5-6 mm. thick in 20 to 30 years old trees and in Singapore, Peradeniya trees the thickness reaches upto 9·5 mm. In a cortex 5 mm. thick the latex tubes occur chiefly in the inner 2 mm., the middle contains a few tubes and the outer 2 mm. practically have no tubes.

The laticiferous vessels are formed from rows of special cells arranged longitudinally which can be distinguished from the neighbouring cells by their greater length and by their contents which are generally brownish due to some colouring matter present in the tissues. The transverse walls of these cells undergo absorption forming long, continuous tube or vessel and also the adjacent vessels communicate with one another by lateral passages forming a net work of articulated laticiferous tissue [Petch, 1911].

The latex generally runs for about half an hour after the cut has been made but in some cases it runs for one to three hours.

The trees may reach an age of 200 years but they are generally tapped up to an average of 30 years.

Yield. It has been reported that four to six years old trees with a minimum girth of 20 inches yield 1 to 3 lb. of rubber per tree each year, seven to nine years old trees 7 to 8 lb. and well developed trees above 11 years old give as much as 12 to 35 lb. of rubber per year per tree [Wright, 1905].

Chemistry. In the cultivated Para rubber of the East there is very little moisture or ash and the percentage of resin and protein is also low. The rubber contains 90 to 96 per cent of caoutchouc. The chemical composition of rubber of *Hevea brasiliensis* is very little affected by the age of the trees though it slightly differs in the trees growing under different ecological conditions. The analyses of rubber by Bamber from Para trees growing in Ceylon is quoted below [Brown, 1914].

TABLE IV

Age of the trees and composition of rubber

	2 years	4 years	6 years	8 years	10-12 years	30 years
Moisture	0·70	0·65	0·55	0·85	0·20	0·50
Caoutchouc	91·20	94·58	94·79	94·60	94·35	93·24
Resin	3·60	2·72	2·75	2·66	2·26	2·32
Protein	4·00	1·75	1·51	1·75	2·97	3·69
Ash	0·50	0·30	0·40	0·14	0·22	0·25

Though it is clear from Table IV that Para rubber obtained from young trees might have more or less the same chemical composition as that from the older trees yet the rubber from the young trees is generally deficient in physical properties as it is soft and weak. Thus it can be concluded that very young trees should not be tapped.

Tapping. The Para rubber trees are considered to be ready for tapping when they obtain a circumference of 18-20 in., at a height of 3 ft. from the ground which generally occurs in a tree 4 to 7 years old.

As the thickness of the cortex varies from 1/8 to 1/2 in. according to the size of the trees, the cut should be sufficiently deep to get maximum flow of the latex because the maximum number of laticiferous tissue is situated in the innermost layer of cortex.

The tapping is generally done at the basal portion of the trunk up to a height of about six feet.

The maximum flow of latex is obtained in early morning or late in the evening when the transpiration rate is low.

The frequency of tapping varies considerably. Thus in Celyon tapping every day in alternate months or every day during rainy season or on alternate days throughout the year showed satisactory results.

It may be remarked in this connection that the yield of latex is very small when the Para rubber tree is first tapped or after a long interval but the yield increases to a great extent in subsequent tappings. The characteristic phenomenon has been termed ' wound response ' because the subsequent incisions on the bark acts as a stimulus for the production of latex [Brown, 1914].

The most generally adopted method of tapping Para rubber trees particularly in Ceylon, South Burma (Fig. 5, VI) and Malaya is the half herring—bone system and the incision is restricted to one quarter of the circumference of the tree. A quarter of the stem tapped in this way is continued for a year. The opposite quarter of the stem is tapped during the second year and then the two opposite remaining quarters in the same way in third and fourth year respectively. In the fifth year the renewed bark on the first quarter is tapped and so on.

There are also other methods of tapping *Hevea brasiliensis* trees as follows :

(A) The double herring—bone system, (B) Full spiral and half spiral incisions, (C) ' V ' incisions, (D) 'Y ' incisions for tapping young trees at the base and (E), Vertical incisions.

But the half herring—bone system is the most advantageous method for the following reasons :

(i) It can be employed in small as in large trees but the double herring—bone system can be employed only in big trees.

(ii) It is not harmful even for young trees but the spiral method is harmful, to plants if used continually.

(iii) In this method only one pot is required at the base of the plant thereby saving a large amount of labour as well as the cost of pots.

(iv) Finally, in this method only a quarter of the stem is involved but the other quarters get a sufficient resting period thereby increasing the yield and longevity of the trees.

Sketches of the different methods are shown in (Fig. 5, I to V) after Harold Brown to whom the writer is deeply indebted for obtaining much information from his book on rubber [Brown, 1914].

It will thus be seen that *Ficus elastica* had undergone a fair trial in experimental cultivation in India as a source of rubber. The yield of rubber per tree and per acre is extremely low and its market value is also very poor in comparison with Para rubber obtained from *Hevea brasiliensis*. (1) The chief reason for its low market value is the presence of a resin about 4 to 20 per cent in the rubber (8·824 per cent in the sample examined) which, hardening in the course of time, annuls the elasticity [Brown, 1914]. (2) The yield is very poor in comparison with the true rubber yielding tree—*Hevea brasiliensis*. (3) The trees do not become productive of yielding latex (from the point of view of commercial rate) until a little advanced in age. (4) If the portion where the incision is made, is exposed to light, the latex coagulates very soon and after half an hour it hardens into gelatinous brownish

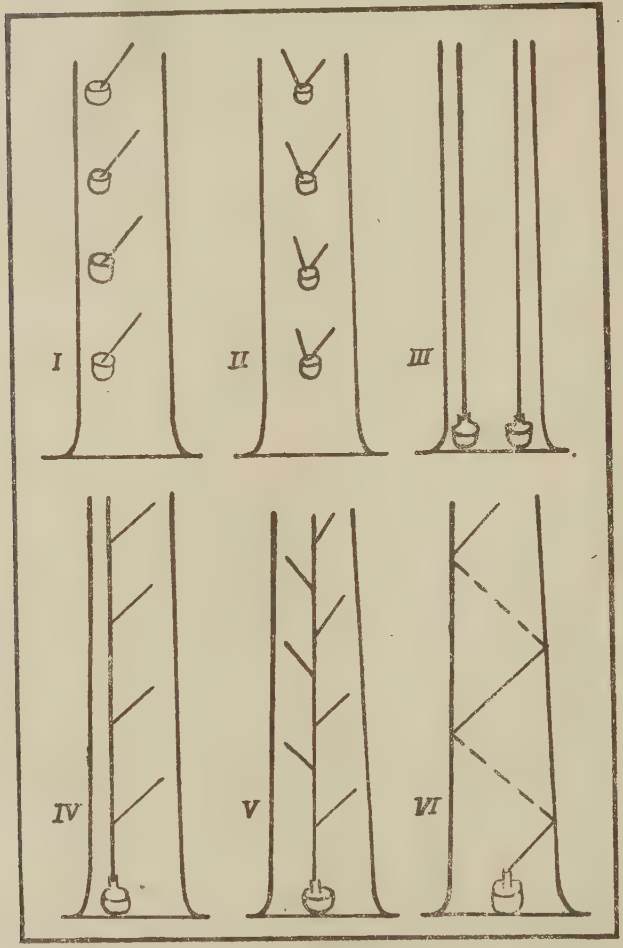

Fig. 5, showing the different tapping systems of *Hevea brasiliensis* (para rubber).

(I) Single oblique incision, (II) ' V ' incisions, (III) long vertical incision, (IV) single herring—bone incision, (V) double herring—bone incision, (VI) spiral incision.

rubber of a brittle nature unlike the milky latex in *Hevea brasiliensis* in which the milk remains liquid for hours after the incision is made. (5) It is difficult to climb over the India rubber trees and collect the latex from all over the low trunks and many branches which are cut on the dorsal side. It is thus not so easy to work with as the true rubber yielding Brazalian tree *Hevea brasiliensis* of the family of *Euphorbiaceae* with its trunk continuously cut in herring—bone fashion and latex is collected in small cups day by day. This milky latex is then placed into enamel buckets and transferred in the vats to be treated chemically and finally spread into sheets and smoked for various marketing purposes. (6) Vast area of land is required for a plantation of India rubber trees. This is not possible to afford in these days of scarcity of food and shelter.

My study of rubber plantation of South Burma and discussions with some of the experts and owners of the plantation and firms have led me to draw the same conclusion as recently found expressions in some of the latest publications dealing with question of rubber production in different parts of the world.

Rubber market

The rubber industry is a delicate and highly complicated world problem to deal with. The solution mainly rests on the balance between demand and supply which seems to be the deciding factor, particularly in an age when synthetic rubber is playing by no means an inferior role than the natural rubber in the marketing of rubber as a whole. The rubber problem is also intimately connected with the economic problem of the labour employed in the cultivation and manufacture of rubber. It varies with as my experience shows in the South Burma, the rise and fall in the price of rice, the staple food for most of the labourers employed in the plantations. Moreover, the quality of rubber plays also an important part in modern industry and the last but not least there exists the time factor in raising a new and re-establishing a damaged plantation. If we take into account the yield from the vast tracts of land now under true natural rubber in rubber yielding areas of the world, and consider carefully the position of synthetic rubber in the world market, it will be clear that such rubber yielding trees as *Ficus elastica*, *Cryptostegia grandiflora* and a few other rubber yielding species will be of negligible value in the present as well as future market even in the event of, God forbid, another global war. It is therefore advisable to concentrate on the production of natural Para rubber in the existing plantations and synthetic rubber, which is particularly suitable for some industrial purposes, and at the same time to maintain a balance between supply and demand.

The Sikkim and Assam plantations of India rubber fig trees are therefore of very little commercial value, but the trees serve the purpose of forming a beautiful avenue with canopy overhead along the Lachen Road for a distance of over two miles. The Spaniards also used them in early times in the Philippines as shade trees along the roadside. Some of them are magnificient specimens and may serve as a source of scrap rubber of inferior quality for the purpose of home industry in emergent condition if necessary. They are also of much interest and admiration to the botanists, the foresters and the travellers to Sikkim and Assam.

Before the global war 'each worker tapped about 350 trees (Para rubber trees) a day to produce about thirty-eight pounds of latex. Over the years the handling of rubber was constantly improved by the planters'. Coagulated in porcelain and aluminium lined tanks by acetic and formic acid, the rubber was then dried and pressed into ribbed smoked sheets (Plate XIV, fig. 7). When baled, it was shipped to the rest of the world chiefly in British, Dutch, and the U. S. A. bottoms. The proportion of rubber shipped in the form of concentrated liquid latex rose rapidly just before the war, and this development will continue now that peace has returned to the East. Another basic technical improvement in natural rubber production is bud grafting. In some cases it has raised the yield from 400 pounds an acre to 1,200 pounds. To-day, some estates are looking forward to yields of as much as 2,000 pounds an acre from bud-grafted trees that deserve to be called the 'synthetics' of the botanical world. 'Moreover, there is the increasing production of synthetic rubber and the total rubber capacity of the world has been rightly estimated at nearly three million long tons.'

Against this background of the world production of both natural and synthetic rubber there will be an enormous supply of rubber to meet the needs of increasing postwar industrial purposes. The question of utilising inferior rubber from Indian rubber plants will not therefore arise for years to come and it is doubtful whether it will arise at all on account of improved cultivation of Para rubber trees and production of synthetic rubber in large quantities.

From 1925 onwards productive capacity of natural rubber gradually increased and reached its climax in 1941. Then came the Stevenson's control plan in 1922-1928 and consequent control of production in the British gardens with a view to maintaining high price. It is true that this rubber control price brought a high price, but soon after it resulted in over supply on account of supply coming to the market from the uncontrolled gardens. The over supply led to the glut as a result of which the price came down as low as 3 to 4 annas per lb. in 1929 to 1931 as I myself found in the plantations during my botanical expeditions in South Burma along the border of Siam.

The present rubber market, however, indicates a good profit as the selling prices of $22\frac{1}{2}$ cents per lb. for the natural rubber and $18\frac{1}{2}$ cents per lb. for synthetic rubber, are adjusted to the prospects of postwar industries of the world for some time to come. But when again all the centres of natural rubber are exploited in full swing, taking into account the large rubber of untapped trees in the plantations of the world, many of which have not been properly worked during the war years, and the introduction of improved and latest scientific methods for the supply of natural rubber supplemented by synthetic rubber, the production will be sufficient to meet the increased demands. It is expected that plantations in Malaya, North East Indies and Ceylon will have a productive capacity of 100,000 long tons annually and plantations in India, Burma, Siam, Sarawak and North Borneo will have pro-

ductive capacity of 10,000 long tons per year. Moreover, this productive capacity will be supplemented by 700,000 tons of synthetic rubber. This supply of both natural rubber and synthetic rubber was estimated to be used by the rubber companies in the United States of America alone to produce 66 millions of passenger car casings and 60 millions of tubes in 1946. 'By 1947 total rubber manufactures may soar to about 1·3 billion according to an estimate by the Committee for Economic Development.'

The question naturally arises whether the true rubber plantation will be started in India in other suitable places or not, of course eliminating the possibility of any future for the Indian rubber tree, *Ficus elastica* and *Cryptostegia grandiflora*. To this question my answer would be, if sufficient unused forest lands are available in rubber zone of South India or North-East and East India, such as the area along the border of Burma—say Chittagong Hill tracts-Manipore valley and southwards extending down to the Arakan bordering south Burma, the low ranges of Duars and Terai regions in the North-Eastern spurs of the Himalayan mountains and the Malabar and Coromondal hills in South India, these may be utilised for growing rubbers along with other timber and useful forest plants with a view to utilising them, rather than if and when emergency arises as experienced in the last global war, wasting time and money in exploring unnecessarily possibilities of obtaining inferior rubber from rubber trees of doubtful economic value. But optimism in dealing with such a variable industry as rubber should be taken with caution. Some of the biotic factors such as labour trouble, famine, economic standard of rubber workers, communication and several other factors influence the fate of rubber industry to a considerable extent.

I herefore agree with the following remark quoted from *Fortune* October, 1946 :

Rubber men may be wrong again about supply this time with an overestimate. The reason is not hard to grasp. The rubber growing regions, as well as other related areas of the East, were built up into an interdependent economy by slowly adding piece to piece. The natural rubber economy, as it existed before the war, depended for one thing on cheap, importable coolies. To feed them it depended on cheap rice. To clothe them it depended on cheap consumer goods, notably textiles from Japan. Even when all these productive factors are obtainable in far greater quantities than they are now, it will be no simple matter to put them together again.

'As for the coolies, the Japanese deported them by the thousands and worked many of them to death. In Malaysia, the labour force of the estates has been depleted to 40 or 50 per cent of pre-war strength. All rubber growing regions are short of cheap rice, the Burma-Siam rice bowl is disorganized. It may be years before textiles as cheap as the Japanese appear again in eastern markets. What is more, even the managers of the economy are no longer present in force. The Dutchmen cannot reach their estates in the most parts of Java, Sumatra and Borneo. In Malaysia, of the original 1,400 estate managers who were there before the war, there are perhaps only three or four hundred available.'

'Rubber may not come out of the East nearly so fast, or nearly so cheap, as some American observers seem to think.'

'In its days of ruin the Stevenson plant proved that rubber men cannot always foretell demand any better than they foretold supply. No sooner had supplies, unforeseen by the British, hit the market than the 1929 crash hit the United States of America. The automen of Detroit, whose needs had helped stimulate the boom, slowed down their assembly lines. Replacement demand for tyres fell off. By 1932 the price of rubber had dived to 3 cents. The moral drawn by the United States of America from the early phase of the Stevenson experience slack with the stretch in rubber prices. The moral drawn by the British from the later, low demand phase was that innocent bystanders were being hit by the United States of America depression. A moral that anyone can draw is that rubber has a habit of hitting men below the horoscope'.

I would therefore advise the Indian rubber lovers : ' look before you leap'.

Acknowledgements

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References

Brown, H. (1914). *Rubber, its sources, cultivotion and preparation*

Burkill, I. H. (1935). *A Dictionary of the Economic Products of the Malaya Peninsula*, I

Hill, A. F. (1937). *Economic Botany*,

Petch, T. (1911). *The Physiology and Diseases of Hevea brasiliensis*

The Controller of Rubber, Department of Supply, New Delhi (1908-1943). *Wild Rubber survey*

Watt, G. (1908). *The Commercial products of India*

( ) (1890). *Dictionary of the Economic products of India*, IV, II.

Wright, H. (1905). *Hevea brasiliensis or para rubber, its botany, cultivation, chemistry and diseases*

REVIEWS

FOOD PLANT SANITATION

By M. E. Parker, [Published by McGraw Hill Book Company, pp. 447 Price $6]

IN this book the author has covered all inportant aspects of sanitary practice in food plants with a view to produce neat and wholesome food under neat surroundings. There are fifteen chapters covering the fundamental principles and various other sanitary aspects covering plant and equipment layout, water supply waste disposal, insects and rodent control, effective uses of detergents, fungicides, germicides, and sanitizers, effective methods of cleaning practice, training of 'sanitarians' and the ways of enforcing sanitary programme and the difficulties involved therein. Two chapters are included to cover the sanitary packaging practice and the sanitary aspects of packaging materials. A very useful inclusion is the appendix giving the important legal regulations covering food manufacture in the U.S.A.

It is a recognized fact that the public is entitled to protection from illness and death caused by eating impure foods. Consumers have also a right to get protection against practices which are offences to hygienic decency. This concept has been very conveniently included in the Federal Food, Drugs and Cosmetic Act of 1938 as 'a food shall be deemed to be adulterated if it consists in whole or in part of any filthy, putrid or decomposed substance or if it is otherwise unfit for food or if it has been prepared, packed and held under unsanitary condition whereby it may have become contaminated with filth'. In this comprehensive treatise the author has kept this in view throughout the discussion of the various principles and methods of sanitary control and inspection technique with a view to aviod legal action under the above provision of the Act and more so for giving the consuming public a healthy and wholesome food.

This book is a singularly useful compilation of the available knowledge in the branch of Food Plant Sanitation and is recommended as a reference or text-book for the Food Technologist, Plant Superintendents, Inspection Agencies, Public Health students and research workers. Every food industrialist in our country should go through this and set his hands and energy to the task of providing a neat and wholesome food from a neat surrounding. (G.S.C.)

SOIL EROSION—ITS PREVENTION AND CONTROL

[Published by the Government of Madras. 1948, pp. 177, Price Rs. 6]

THE rapid depletion of the soil resources of India by erosion and the subsequent effects in lowering the general standard of living of the masses has only recently been realized by the Governments in India. Any book, at this juncture,

which would create real interest in the country on soil erosion and its control is, indeed, welcome. The Madras Government is to be congratulated for having taken a bold step in bringing out a text book on soil erosion for the use of Departmental Officers and for teaching the subject in the Agricultural and Forest Colleges.

The subject matter of the book is divided into eighteen chapters and is profusely illustrated. Lessons of the past as well as of modern times of soil erosion have been presented in Chapter I. Examples of damage caused by erosion in different parts of the world have been cited. The chapter, begins with a definition of soil which is hardly apt. A definition of soil could have been more precise as the one given by Joffe. 'The Soil is a natural body, differentiated into horizons, of mineral and organic constituents, usually unconsolidated of variable depth, which differs from the parent material below in morphology, physical properties and constituents, chemical properties and composition and biological characteristics'. In addition to the description of the destructive processes leading to the accumulation of soil materials, the constructive aspect of soil formation leading to the development of soil profiles should have found a place.

Chapter II deals with the agencies and the types of erosion that are generally met with. The results of erosion in silting up of reservoirs and irrigation canals, reduction in underground water supply, etc. are also broadly dealt with. The chief causes of accelerated erosion are given in Chapter III. Nine causes are enumerated but only four of them have been explained in some detail. Under 'soil variable qualities', only the texture and the structure of soils have been dealt with. But other soil characteristics such as soil depth, permeability, nature of colloids, etc., which are significantly correlated with the erodibility of soils are not touched upon. An elucidation of these factors would certainly add to the value of the book.

Chapter V is well-written and contains much useful information. The question whether 'waste weirs' even in contour bunds, are necessary or not, is still a moot point. The intensities of rainfall as also the peculiar characteristics of the Black soils of the Karnatak do call for, if not waste weirs, some other mode of excess-water disposal. In Chapter VII, the items of dry farming and terracing have been discussed. Soil and moisture conservation problems are interdependent and a great deal of work has been done in India. Hence the subject of dry farming might have usefully been discussed in greater detail in this chapter. The subject of terracing could have been dealt with in more detail and also discussed in Chapter V along with contour bunding. Such important questions as the 'uniform grade' and 'variable grade' terraces, their length and cross sections should find a place in a text book.

Chapter X dealing with the agronomic or the biological aspect of erosion control has been treated cursorily. The effects of various types of mulches and the place of legumes and grasses in erosion control practices are not fully emphasized. The method of laying out contour strip cropping on the land, selection of suitable cover crops, their seed rate, width, which could be adopted with advantage in different soil types, slope, climatic complexes and their ultimate effects in soil development and increased crop production need to be dealt with in a text-book of this kind.

In the suggested land-use recommendations in this chapter, only slope and degree of erosion have been taken into consideration. A major factor such as soil type, which is vital for any land-use planning has been left out.

In Chapters XII, XIII and XV the question of types of dams and the control of stream and river bank erosion has been compiled very satisfactorily. The last chapter dealing with erosion and malaria although of vital importance to India occupies, for a text-book on soil conservation too much space. Lastly, in this volume, one vital omission, is a chapter wholly dealing with *soil conservation survey* of all cultivable areas including suggestions for land classification and land-use planning. No text-book could be considered complete without it. Otherwise, the volume is on the whole, timely, well written, definitely informative and useful. The subsequent volumes to follow on the subject may well be expected to be more comprehensive. The minor printing errors, not a few, are common with all our printers. (J.K.B.)

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